THE SYSTEMATICS OF SOUTH AUSTRALIAN PRECAMBRIAN AND CAMBRIAN STROMATOLITES. PART II

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Summary

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Five new forms of stromatolites from South Australia (*Inzeria conjuncta*, *I. multiplex*, *Jurusania burrensis*, *Katavia costata* and *Kulparia kulparensis*) are described. South Australian occurrences of *Conophyton garganicum garganicum*, *Gymnosolen* cf. *ramsayi* and *Inzeria* cf. *tjomusi*, previously known from the USSR and elsewhere, are also discussed.

Introduction

This paper is a continuation of Preiss (1972) in which the principles of stromatolite classification were outlined and several new forms of stromatolites were described. The glossary appended to Part I also applies to this paper.

Systematics

Group CONOPHYTON Maslov

Conophyton Maslov 1937: 334. Korolyuk 1963: pl. 5, Fig. 3. Komar, Raaben & Semikhatov 1965: 27. Komar 1966: 72. Cloud & Semikhatov 1969: 1037. Bertrand 1968: 170. Walter 1972: 102.

Type Form: *Conophyton lituum* Maslov, from the Derevnin Suite, Lower Tunguska River.

Diagnosis: Non-branching or extremely rarely branching columnar stromatolites with conical laminae, usually thickened and/or contorted in their crestal parts.

Content: *C. cylindricum* Maslov; *C. metulum* Kirichenko; *C. circulum* Korolyuk; *C. garganicum* Korolyuk; *C. miloradovici* Raaben; *C. lituum* Maslov; *C. baculum* Kirichenko; *C. gaubitza* Krylov; *C. ressoti* Menchikoff; *C. cadilnicus* Korolyuk and *C. confertum* Semikhatov.

Conophyton garganicum garganicum Korolyuk (emend.)

FIGS. 1, 2a, 9a, 11, 12a

Conophyton cf. *garganicus* (partim), Glaessner, Preiss & Walter 1969: 1056.

Material: Eleven specimens from Paratoo, S. Aust.

Description

Mode of Occurrence: These stromatolites have been found only in a diapiric raft in the Paratoo Diapir. The basal portion consists of flat-laminated stromatolite, passing up into large domal structures up to 1 m diam. (Fig. 11c). Domes are usually laterally linked, occasionally separated by small interspaces, then dividing into discrete columns, 15–40 cm in diam., with conical laminae. Transverse sections of columns round to oval or lanceolate (Fig. 11b). Columns 1–4 cm apart, with some massive bridges, often slightly bent, with axes non-parallel, diverging at up to 30° (Fig. 11a). Some of this divergence may be due to tectonic disturbances. The original mode of occurrence is not clear because of the discontinuous outcrop; it may have been a bioherm or thick biostrome, perhaps 30 m thick. The only evidence as to the facing of the bed is the upward passage from flat-laminated to conical stromatolites, with apices growing upwards.

Column Shape: Field observation shows that columns are somewhat irregular cylinders, with ragged edges, massive bridges and overhanging laminae. Only one specimen was suitable for reconstruction (Fig. 2a). Columns of round transverse section have a linear crestal zone, while those of elliptical and lanceolate sections have crestal planes in the long axis of the ellipse (Fig. 11b). Specimens studied in the laboratory also show both types.

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The margin structure is very irregular, with numerous large bumps, overhanging peaks and short cornices (Figs. 2a, 11a). Bridges vary in thickness from one or two to several lens of laminae.

Branching: No true branching except actual separation of columns from the domed and flat-laminated base. Rarely a small projection with convex, non conical laminae occurs on the margin of a column.

Lamina Shape: In longitudinal axial sections laminae steeply conical, apical angle generally acute (50–90°) but obtuse angles occur near the base of the columns. Away from crestal zone, laminae usually straight and parallel in longitudinal section, but in places bent downwards near the column margins, producing a shape resembling gothic arches (Fig. 9a).

Crestal Zone: All laminae more or less thickened in crestal zone. Some light laminae greatly thickened. Dark laminae arched up and contorted, often leaving irregular voids filled with sparry dolomite, within the thickened light laminae (Fig. 11f). The crestal line, joining apices of successive conical laminae, is very wavy, with frequent sharp displacements of crests (Fig. 1a). The overall shape of crestal zone is however straight (Fig. 12a); it corresponds mostly to Type III (after Komar, Raaben & Semikhatov 1965, p. 23, Fig. 5) with uneven thickenings and sharp lateral displacements, but some examples of Type II (without lateral displacements) occur. In places, laminae are deflexed immediately outside the crestal zone (Fig. 12b). The diameter of the crestal zone is taken as the width between the limits of thickening of laminae. Out of 33 measurements, 63% lie between 7 and 9 mm, 24% between 5 and 7 mm, and 12% between 9 and 12 mm.

Lamination: Very distinctly banded and striated in better preserved specimens, consisting of straight, parallel, smooth, very thin laminae, either very continuous, or formed by chains of elongated lenses, aligned in definite layers (Figs. 11e, 11f). Two types of primary laminae occur: light (L_1) and dark (L_2). In some specimens L_2 layers grouped into fairly distinct macrolaminae, in which light laminae are thin and subordinate, separated by layers of predominantly L_1 type (Fig. 11f). The appearance of macrolaminae has been exaggerated by the preferential recrystallization of light laminae. L_1 laminae relatively pure and transparent, mostly 0.08–0.1 mm thick, generally of very constant thickness from the edge of the crestal zone to the column margin, never lensing out. They are internally homogenous, composed of xenotopic, almost equigranular dolomite, of grain size from 0.01–0.03 mm. Many grains slightly inequidimensional. Occasional lenticular spar-filled cavities have dark laminae draped around them (Fig. 11e). L_2 laminae darker, much less transparent and somewhat finer grained than L_1 laminae, the fine crystals stained by a pale brownish, possibly organic coloration (Fig. 11e). Most dark laminae 0.02–0.10 mm thick, not as continuous as L_1 laminae, frequently splitting into series of lenses, 0.2–1.0 mm long, and 0.1–1.0 mm apart, aligned parallel and separated by pale laminae. Some dark laminae are continuous for several cm; some have slight, rounded, lenticular swellings. These, as well as the lenses, may be blunt ended, rounded, or pointed. Rarely, they contain significant swellings, the underlying and overlying laminae being draped around them. Relatively large (0.5–2.0 mm) nodules, within a pale lamina (e.g. Fig. 11e) are probably detrital carbonate grains. L_2 laminae composed of equidimensional, equigranular, xenotopic dolomite, of grain size 0.006–0.015 mm. Boundaries of L_1 and L_2 laminae distinct and smooth, but slight recrystallization has made them a little diffuse in places. Macrolaminae, consisting of sets of L_1 laminae, very prominent in some specimens, are 0.4–1.0 mm thick, composed of 5–10 L_1–L_2 lamination pairs, bounded by predominantly light macrolaminae 0.2–0.5 mm thick, often sparry and recrystallized (Fig. 11f).

Statistical Study: Numerous measurements were made on six large thin sections, of the following parameters: (1) thickness of light laminae L_1; (2) thickness of dark laminae L_2; (3) ratio of thicknesses of adjacent dark and light laminae L_2/L_1 and (4) coefficient of thickening, i.e. ratio of thickness of a lamina in crestal zone, to thickness of same lamina outside crestal zone.

The distribution of *thicknesses of laminae* L_1 and L_2 were plotted graphically for thickness intervals of 0.02 mm; the frequencies of intervals were plotted against the mid-point of each interval, for the six specimens (Fig. 1b to g). A comparison of the six graphs for each lamination type shows some variation between specimens, especially for L_2 laminae, which is interpreted as being due to the difficulty of distinguishing single dark laminae and the thinner macrolaminae in some specimens. This difficulty is increased with greater recrystallization, so that one would expect the more re-

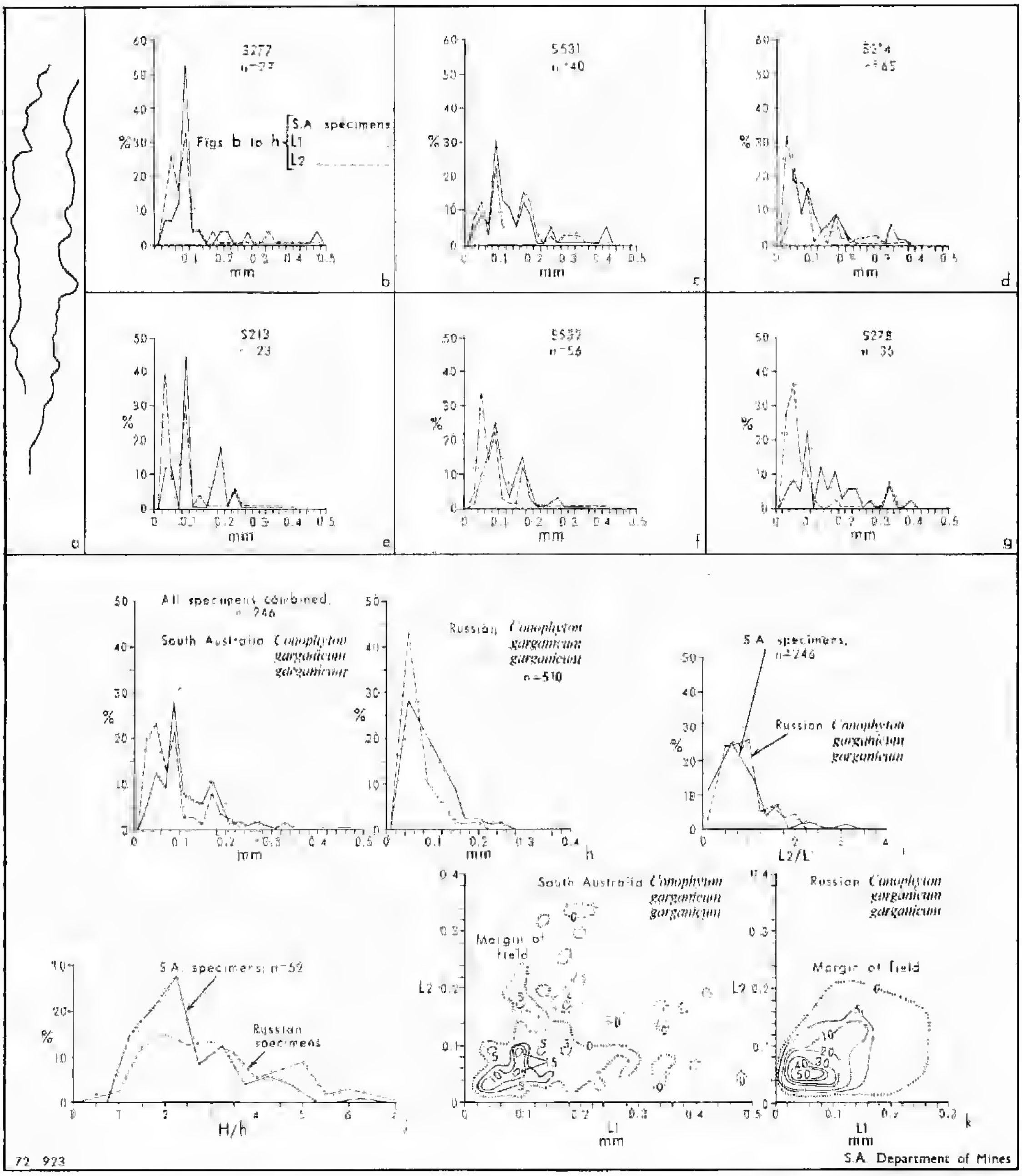

Fig. 1. Diagnostic characters of *Conophyton*: (a)—The traces of the crestal lines of two specimens (S214 at left and S532 at right) drawn from thin section (x1/3); (b) to (g)—Frequency distributions of thicknesses of light laminae L_1 and dark laminae L_2 for 6 separate specimens; (h)—Pooled frequency distributions of lamina thicknesses for all six specimens, compared with data for Russian conophytons; (i)—Frequency distribution of the ratio of thicknesses of adjacent dark and light laminae (L_2/L_1), pooled for all specimens, compared with data for Russian conophytons; (j)—Frequency distribution of the coefficient of thickening of laminae in the crestal zone, compared with Russian conophytons; (k)—Comparison of contour diagrams of the frequency distributions of dark and light laminae (contoured in numbers of readings).

crystallized specimens to have proportionately more numerous thicker laminae (actually thin macrolaminae), i.e. the mean thickness should be higher than for less recrystallized ones. The following table compares mean thickness (in mm) of L_1 and L_2 with degree of recrystallization observed: L_2 means have much greater spread about the total mean than L_1, and the highest means of L_2 correspond to the most recrystallized specimens.

Specimen number	L_1 mean	L_2 mean	Degree of Recrystallization
S214	0.128	0.073	Well preserved
S213	0.107	0.066	Slight
S278	0.145	0.065	Slight
S277	0.111	0.084	Slight
S532	0.115	0.089	Strong
S531	0.087	0.134	Strong
Total mean	0.116	0.085	

The data for the six specimens were combined, replotted, and compared with the distribution curve of the Russian *Conophyton garganicum garganicum* (Fig. 1h). While the L_2 curves are very similar, L_1 has a higher mode in the South Australian form (0.08 to 0.10 mm), with a secondary peak in the interval 0.04 to 0.06 mm, which characterized the Russian form. To some extent, the bimodality is due to errors of measurement arising from the judgement of lamina thickness relative to the scale of the graduated eyepiece, and to the presence of thinner macrolaminae as discussed above.

Ratio L_2/L_1 for Adjacent Laminae: Results from all six specimens were pooled and plotted in intervals of 0.25. The graph compares very closely with that of the Russian form (Fig. 1i). The data may also be represented in the form of a contoured frequency diagram of L_2 against L_1. The shape and position of the maximum are compared with those of contoured Russian plots; they differ only in that the South Australian form has a displaced secondary peak at L_1 = 0.08 to 0.10 mm, L_2 = 0.08 to 0.10 mm (Fig. 1k).

Coefficient of Thickening: Randomly selected light and dark laminae, and macrolaminae, were measured outside the crestal zone (h), then traced into the crestal zone and remeasured (H). H/h was plotted at intervals of 0.5. In a total of 52 measurements, the modal value of H/h is the interval 2.0 to 2.5 (26.9%) while only 15.5% exceed 3.5, and none less than 1.0 occur (Fig. 1j).

Interspaces: Interspace fillings between columns are strongly altered, consisting of homogeneous recrystallized dolomite. Some is of grumous texture, composed of xenotopic equidimensional (0.005–0.01 mm) grains, forming patches 0.05–0.10 mm in diam., set in a sparry matrix of grain size 0.1–0.3 mm. The only observed remnants of primary structure are possible small intraclasts in one specimen.

Secondary Alteration: Fracturing of laminae is restricted almost entirely to the crestal zones of some specimens and marginal zones of others. Portions of the crestal zone are more or less brecciated and recemented in place (Fig. 11d). Contortion frequently occurs within the crestal zone. Immediately outside it, laminae are deflexed; this and the brecciation are effects probably due to compaction during burial. The brecciation of macrolaminae into cleanly broken fragments several millimetres long suggests that the carbonate was already lithified during the deformation (Fig. 11d). In places, on the column margins, laminae truncate underlying laminae. Whether this is due to penecontemporaneous erosion or to sliding of the overlying laminae during compaction could not be determined, but associated brecciation around the column margin suggests the latter possibility. No overfolds or diapiric structures as in *Conophyton garganicum australe* Walter (1972) were observed, supporting the idea that columns were lithified soon after growth.

Columns and interspaces consist entirely of dolomite. The preservation of very fine lamination suggests that dolomitization was probably penecontemporaneous. All laminae are more or less recrystallized; the dark laminae are coarser and more transparent than in the Russian or Western Australian forms. Recrystallization may be due to the low grade regional metamorphism which has affected the Mt. Lofty-Olary Arc. Pale laminae between dark macrolaminae are preferentially recrystallized, emphasizing the distinctness of the macrolaminae. These recrystallized laminae consist of sparry, hypidiotopic to xenotopic inequigranular dolomite, of grain size 0.02–0.10 mm. The most recrystallized specimen is a fine marble, in which dark macrolaminae, approximately 1 mm thick, contain no preserved internal laminae, and consist of xenotopic equidimensional carbonate with interlobate crystal boundaries, of grain sizes 0.02–0.05 mm. The grain size of the light laminae is 0.05–0.10 mm, and in places much coarser. One specimen is extensively silicified. Silicification post-dates the growth of the whole column, and may be related to tectonics and diapiric emplacement rather than to sedimentation. Silica consists of xenotopic quartz aggregates, of grain size 0.05–0.10 mm, in places containing small dolomite rhombs. Portions are completely redolomitized.

Comparisons

The conical lamination with thickened crestal zone, and the absence of branching distinguish this stromatolite from all groups except *Conophyton*. It differs from most conophytons in that the columns are not always parallel, but their original growth orientation is not clear, due to structural disturbance. On microstructural features, it falls into the *Conophyton garganicum* subgroup (*Conophyton garganicum*, *C. miloradovici*, *C. gaubitza*, and perhaps, *C. basalticum* Walter). The closely allied *C. miloradovici* has more irregular and lenticular laminae. *C. basalticum* Walter also has very thin smooth continuous laminae, but lacks the distinctive Types II & III crestal zone. The absence of numerous knotted lenses and sharp swellings distinguishes it from the variety *C. garganicum nordicum*. On these features it was assigned to *Conophyton* cf. *garganicus* by Glaessner *et al.* (1969).

The statistical study confirms the identification as *C. garganicum garganicum*, and distinguishes it clearly from *C. garganicum australe* Walter and *C. garganicum nordicum*. The modes of thicknesses L_1 and L_2 most closely resemble *C. garganicum garganicum*, especially L_2 (mode at 0.04 to 0.06 mm), while most other conophytons have modes at much higher values. *C. garganicum nordicum* has a modal value of L_2 at 0.10 mm, and *C. garganicum australe* Walter at about 0.08 mm. The ratio L_2/L_1 is the most distinctive character for *Conophyton garganicum garganicum*. The modal value is the interval 0.50 to 0.75, which falls within the broader peak of the Russian form (0.50 to 1.00), but distinguishes it from *C. garganicum nordicum* Komar, Raaben & Semikhatov (mode 2.00) and from *C. garganicum australe* Walter (1.0 to 1.5). The coefficient of thickening is less distinctive: the mode at 2.0 to 2.5 does not distinguish *C. garganicum garganicum*, *C. miloradovici* and *C. cylindricum* but excludes *C. garganicum nordicum* and probably *C. g. australe*.

Distribution: Lower Subsuite of the Yusmastakh Suite of the west and east slopes of the Anabar Massif; the Kyutingdin, Arymas and Debengdin Suites of the Olenek Uplift; the Gonam Suite of the Uchur-Maya Region, Ust'-sakharin Suite of Western Priverkhoyan'ye, Mongoshin Suite of the southeast part of the Eastern Sayan, Bul'bukhtin Suite of the Baikalo-Patom Mountains, Satkin Suite of the Southern Urals; in pre-upper Burra Group sediments, Paratoo Diapir, S. Aust.

Age: Early and Middle Riphean; in S. Aust., it is assumed to be early Adelaidean.

Group GYMNOSOLEN Steinmann

Gymnosolen Steinmann 1911: 18. Semikhatov 1962: 219. Krylov 1963: 84. Komar 1966: 88. Krylov 1967: 36. Raaben 1969: 73 (in part). Glaessner, Preiss & Walter 1969: 1057.

Type Form: *Gymnosolen ramsayi* Steinmann, from the Dolomitic Suite of Kanin Peninsula; also widespread in the Southern Urals, the Polyudov Mountains, Kil'din Island, and Tien-Shan, USSR.

Diagnosis: Smooth to gently bumpy, swelling and constricting, walled columns with frequent, γ-parallel, often multiple branching, less frequently slightly divergent branching.

Content: *Gymnosolen ramsayi* Steinmann; *G. levis* Krylov; *G. furcatus* Komar; *G. altus* Semikhatov; "*G. confragosus*" (in part) Semikhatov and *G. asymmetricus* Raaben. Raaben (1969) has included part of the group *Minjaria* Krylov in *Gymnosolen*, chiefly on the basis of microstructural similarity, but Krylov (1963) has clearly distinguished *Minjaria* from *Gymnosolen* by its regular, subcylindrical shape of columns, of constant diameter, and relatively rare and simple branching.

Age: Late Riphean.

Gymnosolen cf. **ramsayi** Steinmann

FIGS. 2b-g, 3a-c, 9b, 10b, 12b,c, 13a

Gymnosolen sp. Glaessner, Preiss & Walter, 1969: 1057.

Material: Five specimens from near Wilson.

Description

Mode of Occurrence: All specimens are boulders from conglomerate and breccia beds within the Tapley Hill Formation on the flank of a small diapir. Only one specimen shows completely separate, discrete, vertical columns, and is interpreted to have been derived from the central portion of a bioherm (Fig. 13a). Of two specimens showing much coalescing and bridging, one also has markedly inclined columns (Fig. 12c). These are considered to represent the marginal portions of bioherms. The provenance of the boulders has not been determined.

Column Shape and Arrangement: Columns straight to gently curved, erect, 1–5 cm diam., with gentle swellings and constrictions (Fig. 2b–g). Transverse sections generally circular to oval, but lobate and rounded-polygonal at branches (e.g. Fig. 3a). Length of columns between branches 5–20 cm. Some columns short (only 2–5 cm long), with rounded or pointed terminations (Fig. 2c,e). Columns presumed to be marginal in bioherms are inclined (as inferred from the asymmetry of laminae and occasional interspace lamination). The gross morphology of marginal columns differs only in their frequent coalescing and bridging, and narrow interspaces (Fig. 3b). One specimen with apparently erect columns is markedly bumpy (Fig. 2d).

Branching: Slightly divergent to β- or, most commonly, γ-parallel. The column expands

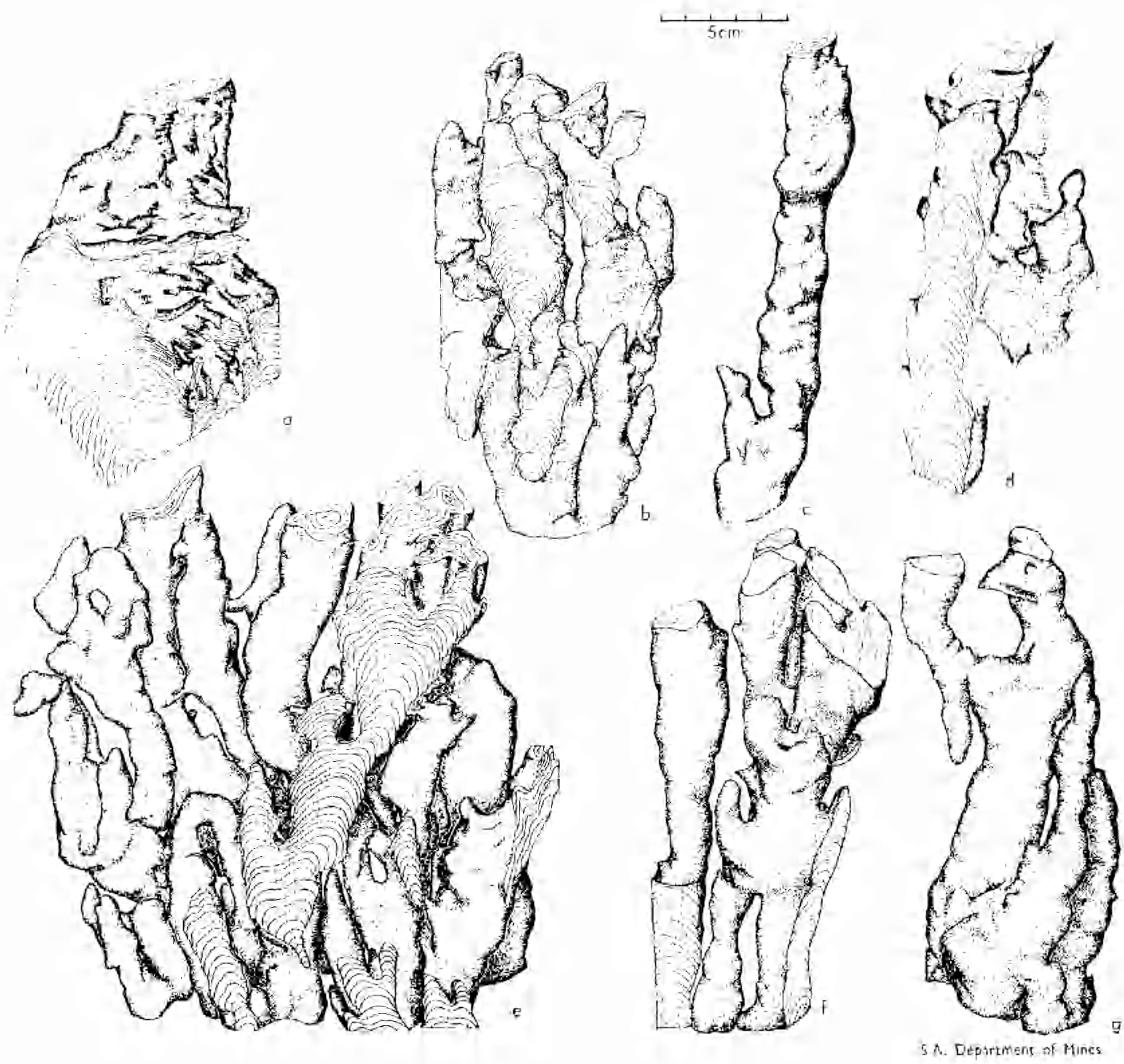

Fig. 2. (a)—*Conophyton garganicum garganicum*, from dolomite raft in Paratoo Diapir. Part of a large column illustrating margin structure. S528; (b) to (g)—*Gymnosolen* cf. *ramsayi*, from boulders in a conglomerate in the Tapley Hill Formation, near Wilson; (b), (c), (e), (f), (g)—Vertical columns interpreted to be derived from a bioherm centre. S388; (d)—Poorly preserved vertical columns. S390.

rapidly, then branches suddenly into two, three or four columns, some branches terminating as pointed projections. Even in the discrete specimens, adjacent columns may occasionally coalesce. The inclined-column specimens branch similarly, but widening of a column before branching is more marked. In these specimens adjacent branches either are frequently linked by massive bridges, or coalesce.

Margin Structure: The surface of columns bears low, rounded bumps, 1 to 2 cm wide, with a relief of a few millimetres. Short, transverse or inclined ribs are exceptional. Mostly it is covered by a wall, up to 3 mm thick, composed of from one or two to ten laminae (Fig. 12b, c). Generally, the marginal zone of columns is recrystallized, but in places, laminae bend down near the column margin and extend parallel to it for up to 2 cm. Even where wall recrystallized, outer lamina sharp, well preserved. In places, an unlaminated selvage, up to 0.5 mm thick, lines the column surface. This post-dates the wall formation, and pre-dates the interspace sediment. In the discrete column specimen, bridges rare; occasionally where two columns are closely spaced, a few laminae may bridge across. Rarely, overhanging peaks occur; especially if draped over an adjacent intraclast: some columns arise from laminae grown over intraclasts. Columns in the inferred marginal specimens partly unwalled; laminae thin and wedge out, forming a smooth margin, but do not extend over it.

Lamina Shape: Varies within broad limits. Gently convex laminae most frequent, varying in section from rectangular to hemispherical. Frequently, laminae develop two or more crests prior to branching, but in some cases, incipient branches are immediately bridged over, and growth of the original column resumed (e.g. the column on the right of the photograph in Fig. 12b). Different lamina shapes occur close together in a column, i.e. degree of inheritance of shape is low. Fig. 9b illustrates commonly occurring shapes. Of laminae measured, 69% have h/d ratio between 0.2 and 0.6, the mode (26%) being the interval between 0.2 and 0.3 (Fig. 10b). (In determining lamina shape, the poorly visible, downturned marginal portions of laminae in the wall had to be excluded). Laminae mostly slightly wavy, with wavelength 2 or 3 mm, and amplitude 0.2–0.5 mm.

Microstructure: Microstructure extensively recrystallized. Where alteration minimal, alternating light and dark laminae of greatly varying thickness form a distinct streaky microstructure (Fig. 12b). *Light laminae* are 0.1–0.5 mm thick. Occasional thicker light laminae (up to 1 mm) may actually be recrystallized macrolaminae. Light laminae are continuous across the column, but thin in the wall zone. Very rarely, they are truncated by micro-unconformities. They are wrinkled and wavy, corresponding to irregularities in the dark laminae, and consist of sparry, equidimensional, xenotopic to hypidiotopic calcite, of grain size 0.01–0.05 mm. Irregular patches, approximately 0.05 mm diam, are stained with a pale brownish (organic?) pigment. *Dark laminae* are 0.05–0.3 mm thick, but pinch and swell rapidly along their length. In many places, they are lenticular, consisting of contiguous lenses or nodules 0.1–0.5 mm long. Usually dark laminae persist across the column, but occasionally lens out completely, so that adjacent light laminae merge. The dark laminae which are thickest in their crests, consist of brown pigmented xenotopic, equidimensional calcite, of grain size 0.005–0.015 mm. In places, dark laminae limonitic. In areas of more pervasive recrystallization, grumous textures are developed in which clotty remnants of dark laminae are set in a matrix of sparry hypidiotopic calcite. Poorly differentiated macrolaminae, 0.5–2.00 mm thick, consisting of up to 8 light-dark lamination pairs, occur in many parts of columns. The internal structure of these is often not preserved, resulting in more or less homogeneous thick dark laminae with wavy, sharp, upper surfaces.

Interspaces 2 mm–5 cm wide; where columns more widely spaced, interspaces filled with silty intramicrite. Intraclasts are flat pebbles 0.5–3 cm long (Figs. 12b, c; 13a), subrounded, variously oriented, and loosely packed (matrix supported). Many stand vertically in the interspace. Some intraclasts are curved, suggestive of a mud-cracked origin. The matrix consists of broadly laminated silty, recrystallized lime mud; fine laminae, 2–5 mm thick, consist of xenotopic calcite of grain size 0.003–0.01 mm, while coarse laminae, of about the same thickness, consist of hypidiotopic 0.03-0.05 mm grain size calcite, with much subangular quartz silt. Laminations of the interspace sediment abut against the column walls, having accumulated after the development of significant relief of columns.

Secondary Alteration: Laminae are extensively altered especially in the marginal wall zone. In places the lamination is completely disrupted around centres of recrystallization, but commonly faint lamination or rows of dark clots are preserved, to indicate the presence of originally continuous dark laminae in the wall zone. The outer few millimetres of columns are commonly recrystallized to coarser, twinned hypidiotopic calcite, of grain size up to 0.3 mm with inclusions of dark lamination relics. In places, an acicular texture is developed in the wall zone, perpendicular to the column margin. The central parts of columns are less affected, but even here, laminae are commonly reduced to dark clots in a sparry calcite matrix. Dolomitization of both interspace and columns is found in some specimens, where anhedral to subhedral rhombs of dolomite, 0.02–0.06 mm in grain size, are scattered more or less uniformly throughout a recrystallized sparry calcite mosaic. Frequently, lenses of coarsely crystalline, clear calcite occur within the lamination. Coarsely sparry patches, cutting across all earlier structures, are probably infillings of solution cavities, since they are closely associated with discordant stylolites. Stylolites are rather rare, and of two generations. The first are concordant with laminae, and contain concentrations of limonite. These are cut by major calcite veins, which in turn are offset by the discordant stylolites mentioned above.

Comparisons

The stromatolites are assigned to *Gymnosolen* on the basis of their column shape, frequent γ-parallel and slightly divergent branching, and wall. In overall column shape and type of branching, presence of pointed projections, shape of laminae and microstructure, the South Australian form closely resembles the type *G. ramsayi*. Slight differences include unwalled patches of columns, occasional peaks and bridges, and in places a slightly bumpier margin structure. *G.* cf. *ramsayi* is distinguished from *G. furcatus* by the absence of markedly γ-parallel, multiple branching and by the presence of pointed projections, and from *G. levis* by its more widely spaced, less markedly bumpy columns. *G. altus* Semikhatov has apparently been affected by a strong cleavage, and its columns are slightly deformed, making comparisons difficult, but it appears to have a more continuous, banded lamination. *G. asymmetricus* Raaben has thinner, smoother laminae than *G. ramsayi*. *G. confragosus* Semikhatov has in part (specimens from the Shorikhin Suite) been reassigned by Raaben (1969) to *Inzeria* (*I. confragosa*); these specimens are distinguished from *G. ramsayi* by their irregular columns, interrupted wall and more frequent peaks and cornices. Semikhatov's specimens from the Dashkin Suite, now considered as Vendian (Krylov *in* Rozanov *et al.* 1969, p. 215), have much smaller, bumpier columns than *G. ramsayi*.

Distribution: Sub-Inzer Beds of the Katav Suite and Minjar Suite of the Karatau Series of the Southern Urals; Niz'ven Suite of the Polyudov Mountains; Carbonate Beds of the Metamorphic Series of the Kanin Peninsula; Kil'din Series of Kil'din Island; possibly the Sparagmites of Norway; Bystrin Suite of Southern Timan; Chatkaragai Suite of Tien-Shan; as clasts in Tapley Hill Formation, 8 km E of Wilson, southern Flinders Ranges, S. Aust.

Age: Late Riphean; in S. Aust., not younger than the Tapley Hill Formation.

Group INZERIA Krylov

Inzeria Krylov 1963: 71. Krylov 1967: 29. Cloud & Semikhatov 1969: 1042. Raaben 1969: 77. Glaessner, Preiss & Walter 1969: 1057.

Type Form: *Inzeria tjomusi* Krylov, from the Katav Suite of the southern Urals, and the Demin Suite of the Polyudov Mountains, USSR.

Diagnosis: Subparallel, usually unwalled, subcylindrical, ribbed columns, frequently with niches containing projections. Branching mostly α- to β-parallel to slightly divergent, rarely γ-parallel or markedly divergent.

Content: *I. tjomusi* Krylov, *I. toctogulii* Krylov, *I. intia* Walter, and probably *I. djejimi* Raaben and *I. nyfryslandica* Raaben. *I.* (*Minjaria*) *nimbifera* Semikhatov may be included, but Raaben (1969a) has placed it in synonymy with *I. tjomusi*, and has partly reassigned *Gymnosolen confragosus* Semikhatov to *Inzeria* (*I. confragosa*). Raaben has, however, considerably broadened the concept of *Inzeria*, placing little importance on Krylov's (1963) criteria of ribbed columns with niche-projections. On this basis, *Aldania* Krylov (*in* Rozanov *et al.* 1969) could perhaps be better included in *Inzeria*. Descriptions of *I. macula*, *I. variusata*, *I. sovinica* and *I. chunnbergica* Golovanov were unavailable, but Raaben's (1969, Fig. 21) illustration of *Inzeria macula* does not resemble any other described *Inzeria*. The new S. Aust. forms are *I. multiplex* and *I. conjuncta*.

Age and Distribution: Late Riphean, widespread in the USSR; Bitter Springs Formation, Central Aust.; Brighton Limestone and Wundowie Limestone, S. Aust.; Hinde Dolomite, and doubtfully, Dook Creek Formation, N.T.

Inzeria cf. **tjomusi** Krylov

FIGS. 3f, g, 4a-g, 13b-e

Material: Three specimens from Burr Well.

Description

Mode of Occurrence: The stromatolites form a lenticular bed, interbedded in green shales, and consist of four or five contiguous gently domed bioherms (Fig. 13c), 2–4 m diam., with a maximum thickness of about ½ m. Towards the west, the bed thins and lenses out gradually; in the easterly extension, columnar stromatolites give way to flat-laminated limestone. The lower portion of a domed bioherm consists of flat-laminated stromatolitic limestone, or contiguous, very broad cumuli (part of which are seen in Fig. 13d), up to 20 cm thick; overlying this (but never seen in sedimentary contact with it), is a zone, up to 20 cm thick, of discrete, vertical, subcylindrical columns, 2–10 cm wide. The base of these columns is an intensely stylolitic zone, in which a thickness of up to several centimetres has been removed by solution (Figs. 13b, d). At the margins of bioherms, the columns become irregular and slightly inclined from vertical. Columns are bridged over by a thin, poorly exposed zone of flat-laminated stromatolites.

Column Shape and Arrangements: Columns short, subcylindrical, with some swellings and constrictions, of diameter 2–10 cm (Figs. 3f, g, 4a-g), height 10–20 cm (the whole thickness of the columnar zone). Transverse sections round, rounded polygonal or slightly lobate. Columns have vertical, straight axes in the central parts of bioherms, but become irregular at the edges.

Branching into discrete new columns rare, perhaps due to the small thickness of the bed. Niche-projections very frequent; they are short, narrow, usually rounded, sometimes slightly elongated, set into niches in the side of the main column, which, most commonly, resumes its former diameter at the top of the niche (Figs. 13b, c; 4a, d, e, g). Occasionally adjacent columns coalesce.

Margin Structure: Due to strong recrystallization of columns the margin structure is obscure. Laminae approach the margin at a high angle, and are not deflexed at their edges; columns always unwalled. Lateral surface of columns with numerous short transverse ribs, up to 2 cm long, occasional overhanging laminae and peaks. In places, adjacent columns linked by bridges up to 5 mm thick.

Laminae Shape: Always gently convex, varying in shape from continuously curved domes to very low, obtuse cones, as illustrated in Fig. 9c. Lamina shape inherited from underlying laminae, without rapid changes in convexity. Ratios of h/d usually low; 91% of laminae have h/d between 0.2 to 0.4 (Fig. 10c). Fine-scale structure of laminae smooth to gently wrinkled.

Microstructure: Strongly recrystallized throughout columns, but in places the gross indistinctly banded structure of laminae is moderately well preserved (Fig. 13e). Relatively thicker light laminae alternate with thinner dark laminae but recrystallization has in places obliterated the distinction. All laminae have diffuse boundaries. *Light laminae* 0.2–2.5 mm thick, commonly significantly thicker at their crests than their edges, especially in the obtusely-conical laminae. They consist of a sparry, equigranular, hypidiotopic mosaic of calcite, of grain size 0.015–0.02 mm, with included small, irregular patches of darker pigmentation. *Dark laminae* either smooth or finely wrinkled (largely due to embayment by recrystallized adjacent light laminae), thickness 0.2–1.0 mm, generally thinner than adjacent laminae. Occasional thinner dark laminae are lenticular, but whether this feature is primary or due to recrystallization is unresolved. Like the light laminae, they are slightly thickened in their crests. Dark laminae consist of xenotopic, slightly inequigranular calcite, grain size 0.005–0.03 mm, stained with a pale brownish pigment.

Interspaces filled with homogeneous recrystallized lime mud, with occasional intraclasts. Calcite xenotopic to hypidiotopic, grain size 0.01–0.03 mm, contains about 5% angular quartz silt. Quartz grains corroded by recrystallized calcite. Occasional flat intraclasts up to 1 cm long, with diffuse boundaries, in parts of interspaces, recrystallized to sparry calcite mosaic, grain size 0.02–0.03 mm.

Secondary Alteration: The whole rock is pervasively altered. While columns are pale grey, transparent in thin section (Fig. 13e), the dark laminae perhaps tinted with organic matter, interspaces are pale buff, probably due to the presence of small amounts of limonite. Neither columns nor interspaces are dolomitized. The

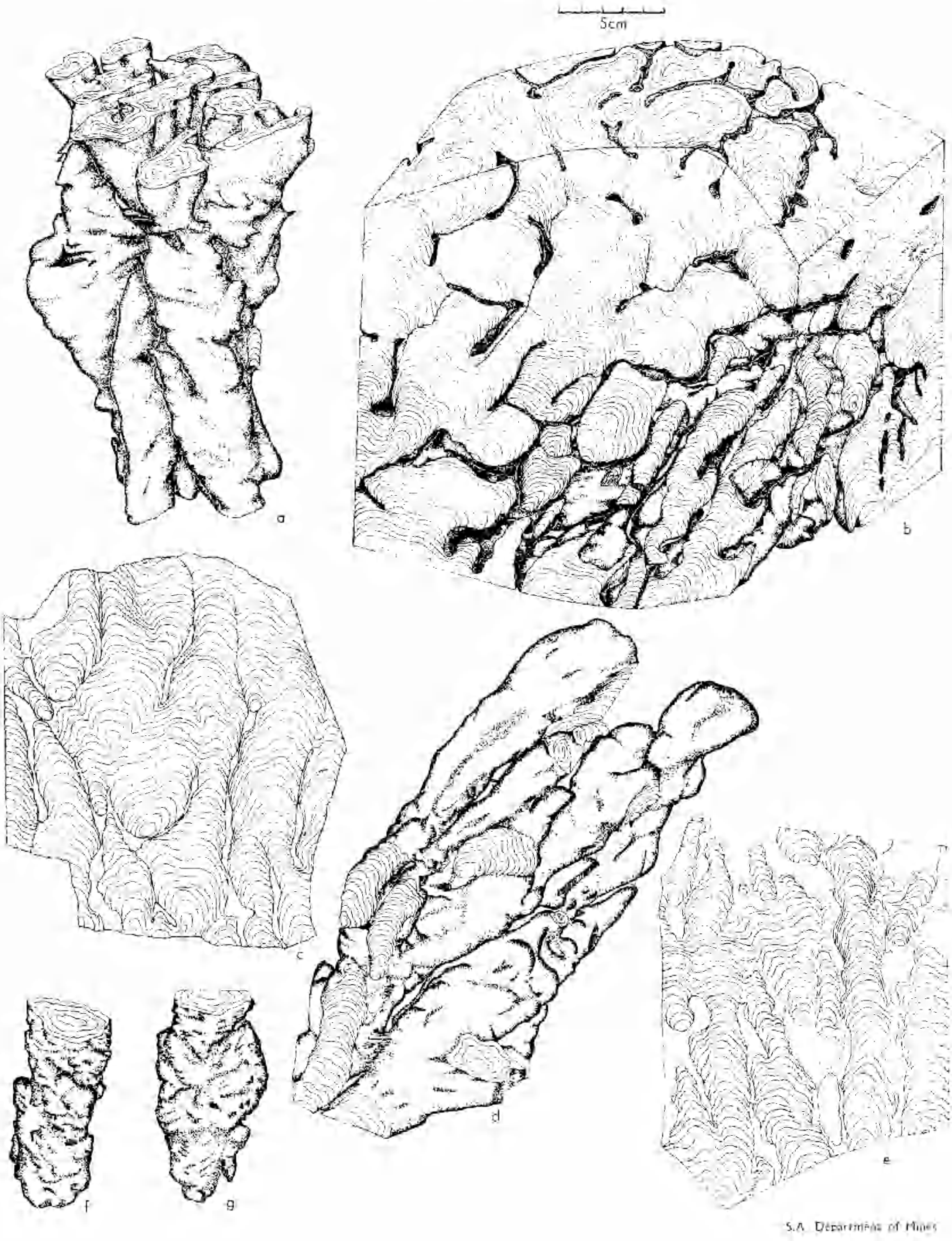

FIG. 3

boundary between interspace and column is always diffuse, obliterated by recrystallization in both. This reduces the reliability of the reconstructions. Highly irregular stylolites with large lobes separate the basal laminated sediment from the discrete columns, with a zone up to 5 cm thick of intense brecciation and late-stage infilling of fractures by coarsely crystalline calcite. Possible remnants of the lower portions of columns, highly enriched in limonite, are sometimes preserved between cross-cutting stylolites (Fig. 13e). Large subspherical nodules, up to 5 cm diam., of coarsely crystalline calcite are very common in the limestone at this locality, mostly located within columns. Twinned calcite crystals in these highly elongated, 1–3 mm wide, up to 3 cm long, vertical or radially arranged. Most crystals terminated upwards; their acute terminations project into the laminated limestone of columns. The major cross-cutting stylolites post-date the coarsely crystalline nodules. Over large areas, columns are completely recrystallized so that lamination is partly or totally obliterated. Such areas consist of xenotopic, to hypidiotopic mosaic calcite, grain size up to 0.5 mm. Where recrystallization incomplete, irregular fragments of disrupted dark laminae surrounded by sparry, recrystallized mosaic calcite.

Comparisons

The presence of ribbed columns with numerous niche-projections places the stromatolites in the group *Inzeria*. They are differentiated from all other Australian forms of *Inzeria* and from *I. toctogulii* Krylov and *I. djejimi* Raaben by their very infrequent branching, consistently gently convex laminae (grading to low-conical rather than rectangular), and their short length of columns. In having subcylindrical, erect, ribbed columns with numerous niche-projections, they closely resemble Russian specimens of *I. tjomusi* Krylov, but differ in the thinness of the zone of columns; the absence of branching may simply be a consequence of the short length of columns. Unlike *I. tjomusi* from the Southern Urals, steeply convex laminae are absent. The microstructure with pinching and swelling or wrinkled dark laminae is similar, but the prominent concentrations of iron oxides along concordant solution surfaces are absent. Until bioherms are found in which the columns had the opportunity to grow to a greater height, so that the mode and frequency of branching can be determined, and which are less recrystallized, so as to preserve the margin structure, no reliable identification is possible.

Distribution: Middle limestone band of the Wundowie Limestone Member, Umberatana Group; Burr Well, northern Flinders Ranges, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean or Vendian of the USSR.

Inzeria conjuncta f. nov.

FIGS. 4h-m, 9d, 10d, 14a, b

Material: Three specimens from near Depot Creek.

Holotype: S402 (Figs. 4a, b, i, j, 14a), from the Brighton Limestone equivalent, 3 km north of Depot Flat H.S., southern Flinders Ranges, S. Aust.

Name: Latin *conjuncta*, meaning joined, refers to the frequent coalescing and bridging of columns.

Diagnosis: *Inzeria* with broad, unwalled, rarely branching, frequently bridged and coalescing basal columns, which divide by α-parallel branching into narrower, unwalled upper columns with occasional α- and β-parallel branches. Niche-projections moderately frequent. Laminae nearly flat to rectangular or gently convex, wavy or wrinkled, with a distinct streaky microstructure.

Description

Mode of Occurrence: Field examination of bioherms is hampered by the very extensive lichen cover on rock faces and by the discontinuous outcrop. Three domed bioherms, up to 50 m long, 3 m thick, occur interbedded in massive oolitic and intraclastic limestone, and cannot readily be differentiated from *Acaciella augusta* in the field. The basal, central portion of bioherms consists of flat-laminated stromatolitic limestone, passing up gradationally into broad columns, 5–20 cm wide with frequent coalescing and massive bridges. Flat-laminated intervals may intervene. At slightly different levels, the broad columns divide by α-parallel branching into 1–5 cm wide columns.

Fig. 3. (a) to (e)—*Gymnosolen* cf. *ramsayi* from near Wilson; (a)—S388, vertical columns probably from a bioherm centre; (b) and (d)—S387, inclined columns interpreted to be derived from a bioherm margin; (c)—S389; (e)—S390, irregular and frequently coalescing columns. Traced from slabs; (f) and (g)—*Inzeria* cf. *tjomusi*, Wundowie Limestone Member, Burr Well, northern Flinders Ranges. S479.

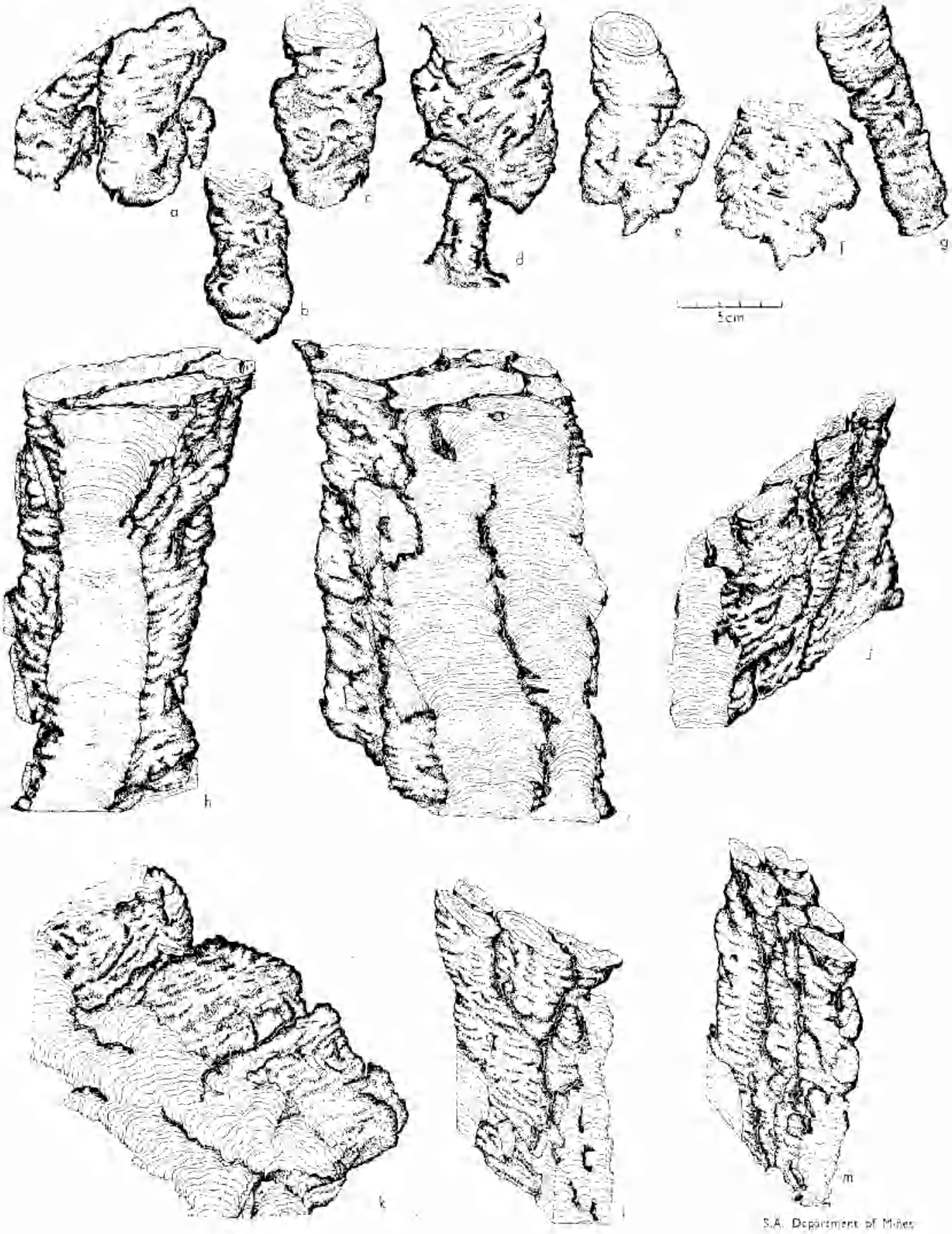

Fig. 4. (a) to (g)—*Inzeria* cf. *tjomusi*, Wundowie Limestone Member, Burr Well, Northern Flinders Ranges. (a), (b) and (c), S542; (d), (f), and (g)—S480; (e)—S479; (h) to (m)—*Inzeria conjuncta*, Brighton Limestone equivalent, Depot Creek; (h), (i), and (j)—Holotype S402, broad basal columns branching into narrow columns; (k)—S403; elongate columns from a bioherm margin; (l) and (m)—S398; narrow upper columns.

Column Shape and Arrangement: Broad columns in lower part of bioherms subcylindrical, up to 30 cm high in their discrete portions, commonly with rounded polygonal transverse sections. Where adjacent columns coalesce, or a wider column branches, transverse sections may be complexly lobate. Overlying narrow columns slightly elongated, from 1 x 2 cm to 3 x 5 cm in transverse section, up to 15 cm long between branches. Columns within central part of bioherm straight, erect (Fig. 4h, i, j) while at margins, they become inclined at 45°, slightly curved and strongly elongated (Figs. 4k, 14b), with swellings and constrictions.

Branching: Niche-projections are formed by unequal, α-parallel branching, or, less commonly, divergent branching; the narrower column is set into the niche in the main wide column, which generally resumes its former diameter after the termination of the projection. Where projections branch divergently, they protrude beyond the margin of the main column. Projections 0.5–4 cm long. Within broad column level, branching (other than by niche-projections) rare. Broad columns then divide by α-parallel, rarely β-parallel branching, into narrower 1–5 cm wide columns, which branch again, less frequently, by α- or β-parallel branching. In marginal zone of bioherm, branching β- to γ-parallel, often with constriction at branching; niches still common, but elongated parallel to the long axes of platy columns (Fig. 4k).

Margin Structure: Lateral surface uneven, with very frequent transverse ribs, some small projections, bumps, bridges, and occasional small peaks. Ribs, 0.5–1 cm wide, may be followed around the column periphery for a few centimetres. Both massive and delicate bridges occur between adjacent columns, and, sometimes, between columns and projections. Niches in the column margins ½ to several centimetres deep; some niches partly closed at one end (Fig. 4h). Occasional niches elongated transversely, grading into prominent ribs (Fig. 4h, j). There is no wall; at the column margins, laminae thin only slightly, and either end abruptly or turn down and wedge out; they do not envelop the lateral surface of the column (Fig. 14a).

Lamina shape varies greatly from broad columns to upper narrow columns. In broad columns most laminae flat, gently convex, or rectangular (Fig. 9d). In places laminae develop two or more crests, then either the column branches (if near the branching level) or the interspace is bridged over, and the column resumes its normal growth (Fig. 14a). In broad columns, measured values of h/d are below 0.25. In the narrow, upper columns, laminae are consistently more steeply convex. Of those measured, 81% lie between 0.3 and 0.6. Columns in the marginal zone of bioherms have laminae strongly asymmetrical towards the exterior of the bioherms, commonly as steeply convex as in the upper narrow columns (60% of h/d between 0.3 and 0.4). Fig. 10d illustrates the distribution of lamina convexities. All laminae wavy, with wavelength 2–4 mm, and locally wrinkled.

Microstructure distinctly streaky with both lenticular and continuous, wavy, swelling and constricting laminae. *Dark laminae* 0.05–0.3 mm thick, wrinkled and wavy, with non-parallel upper and lower boundaries, sometimes grading into aligned clots and lenses. They consist of equigranular hypidiotopic to idiotopic dolomite, grain size 0.005–0.01 mm. Crystals equidimensional and stained a pale green tint, responsible for the green colour of the laminae. No individual grains of pigment could be resolved even at 1200 x magnification. Amplitude of waves and wrinkles 0.2–0.5 mm, and thickness of laminae changes rapidly within a few millimetres. *Light laminae* consist of white to pale grey partly dolomitized sparry calcite of xenotopic to hypidiotopic texture, grain size 0.005–0.035 mm, tending to lens out near column margins where adjacent dark laminae merge. They also contain some coarser detritus, including fine sand-sized, well rounded quartz and feldspar, and small dolomite rhombs similar to those of the dark laminae but less pigmented. Over most of the area of thin sections, dark laminae tend to be grouped into macrolaminae 1–5 mm thick, which, like individual laminae, pinch and swell markedly. There is evidence of minor contemporaneous erosion of thickenings and wave-crests of macrolaminae.

Interspaces: Both lower broad and upper narrow columns are separated by narrow interspaces, 1–20 mm wide, but columns from bioherm margins are almost in contact. The infilling sediment is layered, either by sandy laminae, or by single stromatolitic laminae bridging between columns. Interspace laminae are depressed, concave upwards (Fig. 14a). The carbonate of interspaces is a dolomitized limestone: slightly inequigranular hypidiotopic calcite (partly recrystallized lime mud), grain

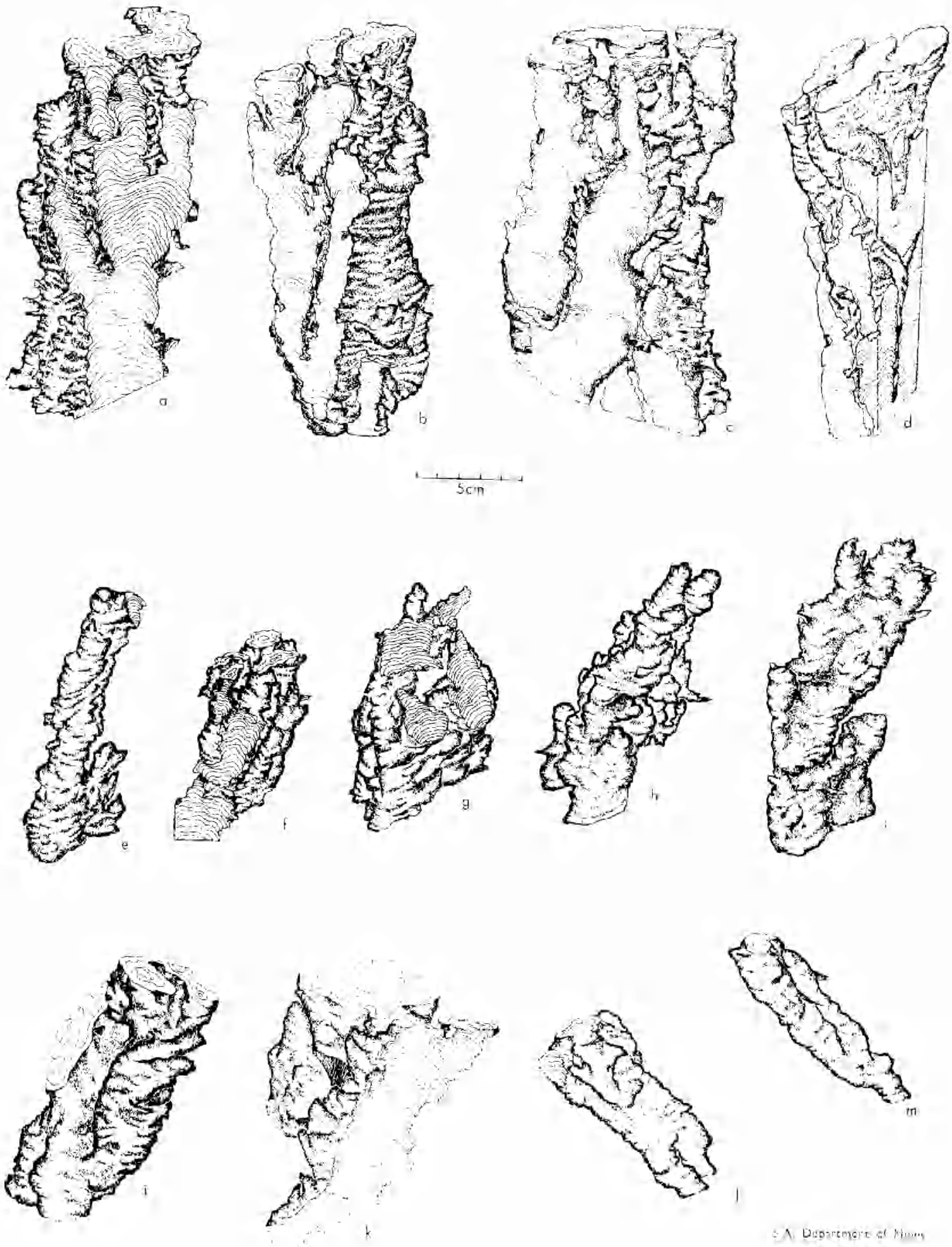

FIG. 5

size 0.005–0.02 mm, contains subhedral rhombs of dolomite, 0.005–0.05 mm diam. In places, quartz sand laminae up to a few millimetres thick abut against the column margins, suggesting that they post-date the growth of that portion of the adjacent column. No carbonate allochems were observed. At times of bridging, the structures had a relief of less than one centimetre, and bridging laminae may be only one or two centimetres apart.

Secondary Alteration: Quartz and feldspar grains, both in columns and interspace sediment, have corroded boundaries; in places their margins are completely replaced by carbonate. While the dark laminae are almost completely dolomitized, the lime mud comprising the light laminae and the interspace filling is only patchily dolomitized and also contains hypidiotopic, coarser calcite due to partial recrystallization. The dolomitization is probably secondary. Stylolites rare except in the bioherm margins, where they separate contiguous columns. Small vughs, up to 3 mm diam., filled with coarse, twinned sparry calcite occasionally cut across the lamination. The origin of the green coloration of dark laminae is not clear, since no particles of pigment could be resolved; the dolomite crystals themselves are tinted. Surface oxidation during weathering either partly removes the colour, or deposits yellow-brown limonite in interspaces or along stylolites.

Comparisons

The stromatolites are difficult to distinguish in the field from *Acaciella augusta* Preiss, but are assigned to *Inzeria* on the following characters: ribbed lateral surface, absence of wall, dominance of parallel branching, and niche-projections. The upper narrow columns also resemble *Katavia* and *Kulparia* but are distinguished by the presence of long transverse ribs, the absence of a wall, and by microstructure; unlike *Katavia* and *Kulparia*, their projections are usually rounded, and set in niches. *I. conjuncta* differs from *I. tjomusi* Krylov and *I. intia* Walter in having frequently coalescing columns, and consistently gently convex, wavy and wrinkled laminae; it lacks the consistently elongated niche-projections and the complex bioherms of *I. intia*. Unlike *I. djejimi* Raaben, its columns are straight, with frequent niche-projections, and rarer branching. *I. conjuncta* is distinguished from *I. toctogulii* Krylov by its less frequent, dominantly α-parallel branching, and by its coalescing and bridging. *I. conjuncta* is especially similar to *Aldania sibirica* in margin structure and microstructure, but has more irregular and coalescing columns. As pointed out above, *Aldania* might be better included in *Inzeria*.

Distribution: Brighton Limestone equivalent, 3 km north of Depot Flat H.S., southern Flinders Ranges, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean of the USSR.

Inzeria multiplex f. nov.

FIGS. 5, 9e, 10e, 14c, d, 15a

Material: Six specimens from near Melrose and Yednalue.

Holotype: S385, from the Brighton Limestone equivalent, 8 km NW of Mt. Remarkable, near Melrose, S. Aust. (Figs. 5a-i, 14c, d).

Name: Latin *multiplex*, meaning complex, manifold or with many parts.

Diagnosis: *Inzeria* with frequent, dichotomous to multiple, α- and β-parallel to slightly divergent branching, and rarer branches arising from niches. Columns have irregular transverse sections. Margin bears ribs, bumps and short projections. Laminae gently convex, smooth to wrinkled, with regularly streaky microstructure.

Description

Mode of Occurrence: Due to poor outcrop, the exact mode of occurrence at Mt. Remarkable is not known; a large bioherm is inferred, since, when followed along strike, the stromatolitic bed passes into massive intraclastic limestone, but the contact is not exposed. At Yednalue, the stromatolites form a very thick bed, which has not been traced laterally. In outcrop, the stromatolites at Mt. Remarkable resemble laterally linked forms, and columns become discernible only when the rock surface is cut.

Column Shape and Arrangement: Columns tuberous to subcylindrical, erect to inclined (Figs. 5; 14c, d), with straight or gently curved axes; occasional columns sharply bent, especially when associated with coalescing. Height

Fig. 5. (a) to (m)—*Inzeria multiplex*, Brighton Limestone equivalent, southern Flinders Ranges: (a-i)—Holotype S385, west of Mount Remarkable; (j, k)—S499. Float specimen, east of Yednalue; (l, m)—S498. Outcrop specimens, east of Yednalue.

of columns between branching 4–20 cm. Transverse sections of columns round or rounded polygonal to irregular and lobate at points of branching or coalescing. Columns which may be variously elongated, vary from 1 to 5 cm in diam. At top of bed, columns frequently bridged by continuous, laterally linked layers.

Branching very frequent and complex, either arising from niches in the parent column (Fig. 5i), or, most commonly, by equal division (Fig. 5a, b, c), usually β-parallel, rarely α- or γ-parallel, or slightly divergent (Figs. 14c, 15a). Adjacent columns frequently coalesce, especially in the upper part of bed.

Margin Structure: Column margins irregular, with numerous, short transverse ribs, low bumps and some slightly overhanging laminae. Bumps and ribs locally grade into very short, outgrowing projections, less than 1 cm long, which are more common than projections set in niches, especially in the Mt. Remarkable specimens (Fig. 14d). There is no wall; commonly gently convex laminae terminate at the column margin, without bending over, sometimes overhanging to form small peaks and cornices. Small portions of column margins relatively smooth. Bridges involving any number of laminae are common, especially near top of bed.

Lamina Shape: Almost always gently convex (Fig. 9e); even in the narrowest columns h/d does not exceed 0.5. Of laminae measured, 93% have h/d between 0.1 and 0.4, the mode (40%) being in the range between 0.2 and 0.3 (Fig. 10e). Laminae may be doubly-crested, prior to branching. On a small scale, laminae broadly wavy, and in places slightly wrinkled.

Microstructure: Alternation of light, sparry laminae and dark, iron-stained laminae, with indistinct boundaries and varying continuity. In places, laminae grouped into macrolaminae 1 or 2 mm thick. Boundaries between laminae frequently wrinkled. *Light laminae* 0.1–1.5 mm thick, usually constant across the column width, smooth, wrinkled or wavy (Fig. 14c), with parallel upper and lower boundaries. Varying abundances of fine quartz sand and silt are incorporated in the light laminae, which consist of hypidiotopic to idiotopic carbonate, grain size 0.01–0.03 mm. Grains equidimensional, sometimes euhedral. *Dark laminae* thinner, generally 0.1–0.5 mm, but pinch and swell across the column width; crests of laminae commonly thickest. Dark laminae grade from smooth to wrinkled, and frequently become discontinuous, forming chains of clots and lenses up to 1 mm long, separated by sparry carbonate (Fig. 14c). Dark laminae, clots and lenses composed of reddish-brown iron-stained, xenotopic carbonate, grain size 0.003–0.01 mm.

Interspaces: Columns generally closely spaced, interspace width 1 mm–3 cm. The sediment is different in the two areas of occurrence.

(1) At Mt. Remarkable, it is broadly laminated reddish dolomicrite; laminae 1–4 mm thick, generally flat or slightly concave upwards. Darker laminae generally thinner (up to 1 mm), of xenotopic dolomite of grain size 0.003–0.005 mm, alternating with thicker, paler, laminae, up to 4 mm thick, of xenotopic dolomite, 0.005–0.015 mm grain size, with a high percentage of terrigenous detritus (angular quartz silt of grain size 0.02–0.05 mm, and occasional mica flakes). Intraclasts up to 1 cm long, 2 mm thick, locally present in interspace, generally standing vertically or inclined (Figs. 14c, d).

(2) At Yednalue, the interspaces are filled with unlaminated sandy limestone, with quartz and feldspar grains, 0.1–1.0 mm grain size, subrounded to well rounded, all embayed by hypidiotopic to idiotopic calcite cement of grain size up to 0.6 mm. Sand grains mostly tightly packed, in places separated by a greenish argillaceous matrix (Fig. 15a).

Secondary Alteration: Specimens from Mt. Remarkable consist entirely of dolomite, while those from Yednalue are calcite. Mt. Remarkable specimens are, however, better preserved; the idiotopic and hypidiotopic dolomite probably formed during early diagenesis, but did not destroy the fine structure of the stromatolites. The dolomitic rock may have proved more resistant to later recrystallization, which has in both areas disrupted the fine lamination to a greater or lesser extent. In addition, cleavage is well developed at Yednalue, and the columns are slightly deformed, so that metamorphism may partly account for the greater recrystallization here. Occasional concordant slightly sutured stylolites follow the lamination, sometimes affecting several adjacent columns, but all are cross-cutting on a fine scale. Greenish argillaceous material is concentrated in the stylolites. Some stylolites follow column margins and thus remove the minor surface features of columns (Fig. 15a). Tectonic veins are filled with quartz or calcite.

Comparisons

The stromatolites are assigned to *Inzeria* because of their ribbed columns with projections, but they frequently resemble *Baicalia* in their tuberous shape; *Baicalia*, however, much more often has divergent branching, more overhanging laminae, and a distinctly banded microstructure. In having some α-parallel branching, they resemble *Kussiella* Krylov and *Acaciella* Walter, but are distinguished by their frequent β-parallel branching and branching from niches. *Inzeria multiplex* is distinguished from *I. tjomusi* Krylov, *I. intia* Walter, and *I. conjuncta* Preiss by its very frequent branching, and rare projections set in niches. In these features it resembles *I. toctogulii* Krylov and *I. djejimi* Raaben, but *I. toctogulii* has more regular, cylindrical columns, while *I. djemimi* has steeply convex laminae.

Distribution: Brighton Limestone equivalent; 8 km NW of Mt. Remarkable and 12 km E of Yednalue, southern Flinders Ranges, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean of the USSR.

Group JURUSANIA Krylov

Jurusania Krylov 1963: 81. Raaben 1964: 93. Krylov *in* Rozanov *et al.* 1969: 195. Cloud & Semikhatov 1969: 1045. Semikhatov, Komar & Serebryakov 1970: 166. Bertrand-Sarfati 1972: 52.

Type Form: *Jurusania cylindrica* Krylov, from the Katav Suite of the Southern Urals.

Diagnosis: Even, parallel, subcylindrical columns with round or oval transverse sections and rare, dichotomous α-parallel branching. Columns partly walled, partly bear downward directed peaks and overhanging laminae, frequently covered with an unlaminated selvage.

Content: *Jurusania cylindrica* Krylov, *J. tumuldurica* Krylov, *J. nisvensis* Raaben and *J. judomica* Komar & Semikhatov. *J. sibirica* Jakovlev has been transferred by Krylov (1969) to a new group, *Aldania*, but Semikhatov, Komar & Serebryakov (1970) retain its assignment to *Jurusania*. Bertrand-Sarfati (1972) has erected new forms *J. derbalensis*, *J. lissa*, *J. alta*.

Age: Late Riphean to Vendian.

Jurusania burrensis f. nov.

FIGS. 6a-h, 9f, 10f, 15b-c, 16a

Material: Four specimens from Burr Well.

Holotype: S543 from the upper limestone band of the Wundowie Limestone Member, Burr Well, northern Flinders Ranges, S. Aust. (Figs. 6d, e, f, 15e).

Name: After the Burr River, on the bank of which the stromatolites occur.

Diagnosis: *Jurusania* with smooth to gently bumpy, partly walled columns and local, short peaks and overhanging laminae. Lamina shape gently convex to subconical, laminae lenticular with diffuse, streaky microstructure. Columns partly covered by an unlaminated selvage.

Description

Mode of Occurrence: The stromatolites occur in lenticular beds of contiguous spherical and subspherical bioherms up to 2 m diam. (Fig. 15c). The bioherms consist of 3 concentrically arranged zones, capped by an undulating columnar zone. Bioherm cores up to 50 cm thick consist of irregularly pseudocolumnar and columnar-layered stromatolites of dark grey limestone, overlying sandy limestone with large, reworked intraclasts. Cores surrounded by concentrically laminated zone, from which long straight, parallel columns arise. At bioherm margins, columns slightly inclined, rarely subhorizontal; generally columns remain subparallel throughout the bioherm, but show more bridging and coalescing at margins. Spherical bioherms, mutually in contact, overlain by flat or broadly undulating 1 m thick beds of columns with numerous bridges and pseudocolumns.

Column Shape and Arrangement: Columns long, straight, parallel or radially arranged, cylindrical or subcylindrical. In one specimen from near the base of a bioherm, columns somewhat inclined, irregular, tuberous, and of strongly elliptical or lobate transverse section (Fig. 6b, c); otherwise transverse sections round or slightly elliptical. Columns mainly smooth, with only occasional low, broad bumps (Figs. 6a-d, 15b, d, e); single columns generally have constant diameter, 5-10 cm for basal columns (Fig. 6h) and 2 cm for upper, narrow columns (Fig. 6d, e, f). Length of columns between branches may exceed 30 cm; the whole columnar zone of bioherms is up to 1 m thick. Columns in the overlying undulating bed rather short, and frequently bridged, apparently arising from basal, flat-laminated stromatolites (Figs. 6a, 16a, specimen S481, but the exact location of this specimen in the bioherm is not certain).

Branching rather infrequent especially in narrow, uppermost columns, which may be up to

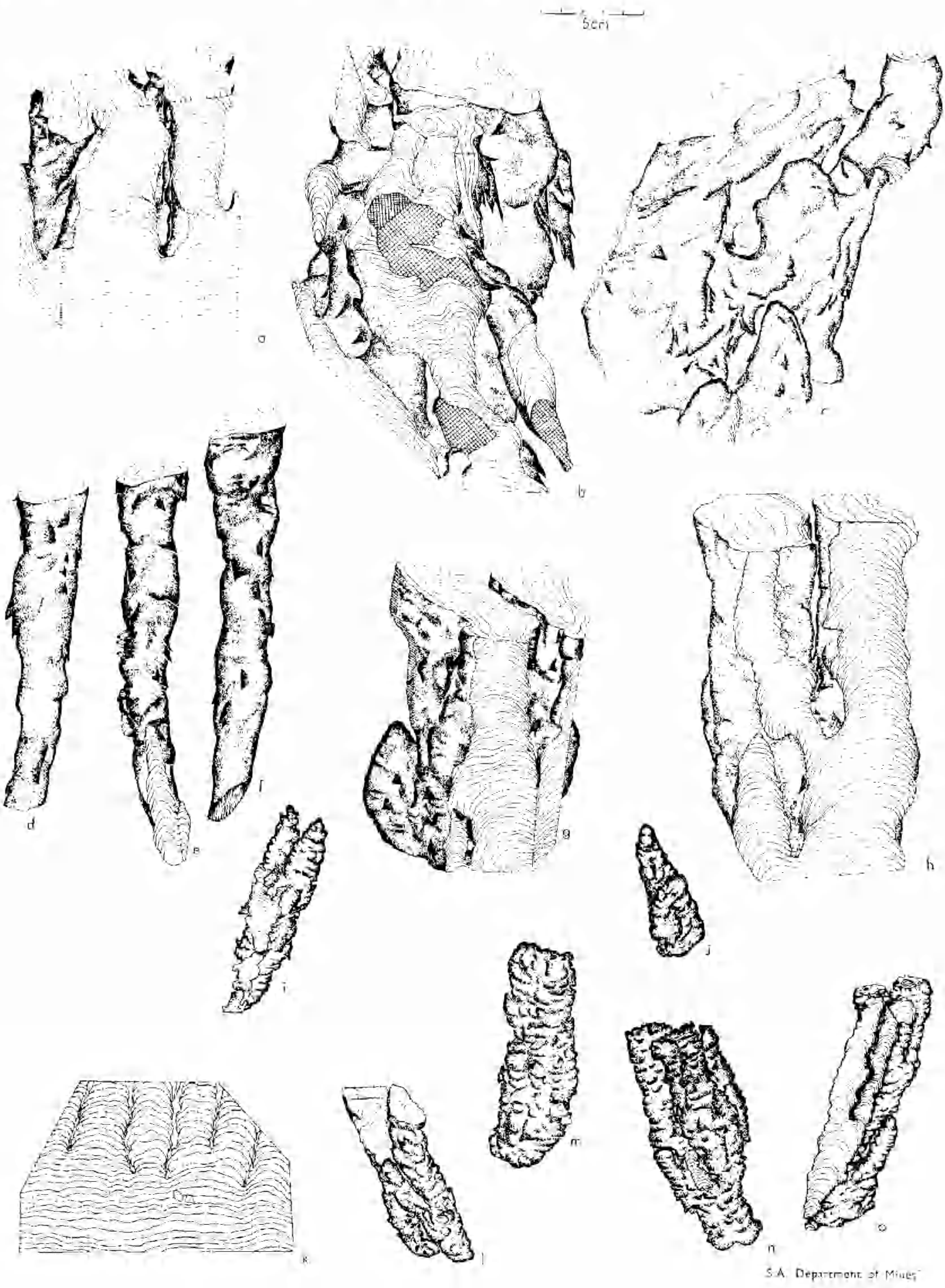

FIG. 6

30 cm long between branches, but more often terminate their growth before branching. Branching always dichotomous, either α- or slightly β-parallel (Figs. 6g, h). Occasionally two neighbouring columns may coalesce, especially in upper parts of bioherms.

Margin Structure generally smooth, walled or unwalled, bearing only broad low bumps several cm wide and of relief up to 5 mm (Figs. 6a-h). Laminae generally approach the margin at an acute angle, but the actual margin is frequently removed by stylolites. In areas not affected by stylolites, laminae either terminate at margin, or extend down for a distance of up to 1 cm to form a patchy wall (Fig. 15d, e). In a few places, laminae overhang slightly to form small peaks, a few mm long (Fig. 6e, f, g). Large overhanging peaks developed only on the irregular columns (Fig. 6b), from the lower parts of bioherms. Considerable areas of smooth columns coated with a selvage, 0.2–1.0 mm thick, of unlaminated very fine grained calcite (Fig. 15d).

Lamina Shape varies to some extent with column width, but most laminae gently convex with relief about 1 cm (85% have h/d between 0.2 and 0.5, Fig. 10f); a few narrow columns have steeply convex to subconical laminae (Fig. 9f). Laminae smoothly curved, micro-unconformities rare. Lamina shape always inherited from the underlying laminae, so that no marked, rapid changes occur. Fine scale structure of laminae lenticular and very gently wavy, with wavelength of 2–5 mm, amplitude 0.1 mm.

Microstructure: The dark limestone comprising the pseudocolumnar bioherm cores is almost entirely recrystallized, and even the lamination is rarely preserved. Lamination in columnar parts of bioherms diffuse, streaky, consisting of alternating, finely wavy, lenticular, dolomitized sparry pale laminae and darker, micritic laminae, which intergrade. *Micritic laminae* recrystallized to microspar, grain size 0.005–0.015 mm, of xenotopic, polygonal, equigranular texture; they have very vague boundaries, and vary in thickness from 0.2–0.5 mm over short distances. In places, laminae thin and terminate laterally, or consist of short, aligned lenses a few millimetres long. *Sparry laminae* 0.1–0.5 mm thick, pinching and swelling but more continuous across column width, consist of hypidiotopic to xenotopic calcite, grain size 0.01–0.03 mm, with scattered subhedral dolomite crystals, grain size 0.015–0.06 mm. In places, laminae almost completely dolomitized, consisting of closely packed hypidiotopic dolomite with remnant interstitial sparry calcite. Sparry laminae may also be completely recrystallized, with little dolomitization, to a hypidiotopic mosaic of grain size up to 0.2 mm. The unlaminated selvage present in places on column margins consists of xenotopic calcite mosaic, grain size 0.005–0.02 mm; its origin is not clear (see secondary alteration).

Interspaces: Columns 0.5–2.0 cm apart. Interspaces filled with poorly bedded intramicrite, partially dolomitized. Intraclasts mostly flat limestone pebbles, 0.5–3 mm thick, 2–30 mm long, generally lying parallel to bedding, or standing vertically in narrowest interspaces (Fig. 15d). The flat pebbles, which commonly have rounded margins, consist of xenotopic, equigranular mosaic calcite of grain size up to 0.01 mm, and contain scattered subhedral dolomite crystals, grain size 0.010–0.015 mm. Subrounded to well rounded quartz and feldspar sand grains occur in places. Intraclasts moderately loosely packed, so that some in contact, some not; sediment was probably matrix-supported. The matrix, probably originally micritic calcite, recrystallized to xenotopic inequigranular texture, grain size up to 0.015 mm, occasionally with scattered dolomite crystals. The matrix may be preferentially dolomitized. In the specimen apparently from the undulating bed capping bioherms, interspaces filled with markedly upward concave laminated, recrystallized lime mud, without intraclasts; laminae somewhat thicker (approximately 1 mm) and more regular than those of the stromatolite columns.

Secondary Alteration: Even the finest calcite laminae have probably undergone some recrystallization to form a very fine grained calcite mosaic. Dolomitization apparently postdates this, as subhedral dolomite crystals cut across the calcite mosaic. In places, especially near

Fig. 6 (a) to (h)—*Jurusania burrensis*, Wundowie Limestone Member, Burr Well, northern Flinders Ranges: (a)—S481; basal columns arising from undulating stromatolites; (b), (c)—S483; irregular columns at bioherm margin; (d), (e), (f)—Holotype S543; regular narrow upper columns; (g), (h)—S482; regular broad, lower columns; (i) to (o)—*Katavia costata*, Brighton Limestone equivalent, Depot Creek, southern Flinders Ranges; (i), (j), (l), (m), (n), (o) Holotype S175; narrow, subcylindrical columns; (k)—S519; basal columns arising from undulating stromatolite.

column margins, laminae are completely reconstituted to a coarse, xenotopic, polygonal calcite mosaic, grain size up to 0.5 mm; these, in turn, contain subhedral dolomite crystals, as well as disrupted remnants of micritic laminae. The origin of the unlaminated selvage is not clear; wherever it was observed, laminae are somewhat coarsely recrystallized immediately adjacent to it inside the column, and the selvage may simply be the outermost lamina of the wall preserved from recrystallization, but this is not certain since the selvage is unlaminated, and laminae cannot usually be traced directly into it. There are at least two generations of calcite veins: the earlier ones are more irregular, finer grained, and contain dolomite rhombs, suggesting that they pre-date at least one period of dolomitization. The younger veins are straight, more coarsely crystalline, and post-date dolomitization. Dolomitization in these stromatolites is, at least in part, very late diagenetic.

Comparisons

In having long, straight, infrequently branching columns without rapid changes in diameter, these stromatolites are distinguished from all but *Minjaria* Krylov and *Jurusania* Krylov. They are distinguished from other α- or β-parallel branching stromatolites (*Boxonia* Korolyuk, *Acaciella* Walter and *Katavia* Krylov) by their infrequency of branching. *Minjaria* Krylov, however, has a ubiquitous wall and lacks peaks and overhanging laminae. *Jurusania* Krylov may have either a patchy wall or no wall, numerous peaks, and frequently a selvage covering columns. *J. burrensis* is intermediate between *Minjaria* and *Jurusania* but is assigned to the latter because of its patchy wall and the presence of peaks. *J. burrensis* differs from *J. cylindrica* Krylov in having a better developed wall, smaller and fewer peaks, and less well defined lamination; however, lamina shape is similar. *J. tumuldurica* Krylov is distinguished by its consistent, well defined ribs and general absence of a wall. *J. burrensis* is distinguished from *J. nisvensis* Raaben by its much more even, smooth columns which do not grade into or alternate with pseudocolumns and laterally linked stromatolites; also, there are no sharp changes in lamina shape as in the latter form. *J. judomica* Komar & Semikhatov has larger, often strongly elongated columns, lacking a wall. *J. derbalenis* Bertrand-Sarfati and *J. alta* Bertrand-Sarfati also lack walls and have ragged column margins. *J. lissa* Bertrand-Sarfati is distinguished by the absence of peaks and cornices, and by more frequent branching.

Distribution: Upper limestone band of Wundowie Limestone Member, Burr Well, northern Flinders Ranges, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean or Vendian of the USSR.

Group KATAVIA Krylov

Katavia Krylov 1963: 94. Raaben 1969: 83. Glaessner, Preiss & Walter 1969: 1057.

Type Form: *Katavia karatavica* Krylov, from the Katav Suite of the Southern Urals.

Diagnosis: Predominantly β-parallel branching straight, subcylindrical, walled columns with a markedly bumpy margin structure.

Content: *Katavia karatavica* Krylov and *Katavia costata* f. nov.

Age: Late Riphean.

Katavia costata f. nov.

Katavia sp. nov. Glaessner, Preiss & Walter 1969: 1057.

FIGS. 6i-o, 9g, 10g, 16b-d, 17a

Material: Seven specimens from near Depot Creek, S. Aust.

Holotype: S175 (Figs. 6i, j, l, m, n, o, 16d) from the Brighton Limestone equivalent, Depot Creek, southern Flinders Ranges, S. Aust.

Name: Latin *costata*, meaning "ribbed", refers to the short ribs present on the lateral surface of columns.

Diagnosis: *Katavia* with very closely spaced parallel columns, a thin wall, very indistinct and wrinkled laminae, and a prominently bumpy and ribbed margin structure with some very short pointed projections.

Description

Mode of Occurrence: The stromatolites form two lenticular bioherms, 5 m thick, and up to 100 m long, in the upper, pink dolomite member of the Brighton Limestone equivalent. The basal one metre consists of wrinkly flat-laminated dolomite, with concordant stylolites. This zone gives rise directly to narrow, parallel columns (Fig. 6k), which continue throughout the height of the bioherm (Fig. 16b). At frequent intervals columns cut by horizontal, concordant stylolites. The upper surfaces of bioherms not exposed. At margins of bioherms columns become inclined at about 45° (Fig. 17a), but no horizontal columns were observed.

Column Shape and Arrangement: Columns long, straight, very closely spaced, diam. 0.5–3 cm, most commonly 1–2 cm (Fig. 16d). Most columns vertical, except near bioherm margins. Cross-sections round to polygonal, often resembling mud-cracked polygons (Fig. 16c). Columns may be 5–20 cm long between branches: occasional columns only a few cm long have pointed terminations (Figs. 6i, j, l, m, n, o).

Branching moderately frequent, predominantly β-parallel: a column 1.0–1.5 cm diam. widens gradually to 2–3 cm, then divides into two, less often three, narrower columns (1–1.5 cm in diameter). α-parallel branching from broad columns does not occur. Some branching very slightly divergent.

Margin Structure: Lateral surface of columns markedly bumpy and ribbed (Fig. 6i-o). Equidimensional bumps, 0.3–1.0 cm diam., with a relief of 2–5 mm most common. These grade into transversely elongated ribs, which partly surround the columns. Small, pointed projections up to 1 cm long moderately frequent (Fig. 6i, l), and in places slight niches in the column margin (Fig. 16d). Overhanging peaks extremely rare; bridges absent in specimens studied. Near column margin, laminae turn down steeply to cover lateral surface for short distances, so that only two or three laminae form the wall (Fig. 16d), which is developed almost everywhere, covering all bumps, ribs and projections.

Lamina Shape: Laminae in basal, flat-laminated portion poorly preserved, but appear to be wavy and wrinkled. The lowest narrow columns generally have gently convex, wavy and wrinkled laminae, but degree of convexity increases upwards. Undulations have wavelength 2–5 mm. Fig. 9g illustrates commonly occurring lamina shapes. 62% of laminae measured have h/d between 0.3 and 0.5 (Fig. 10g). Most laminae hemispherical, some approach rectangular shape. Laminae near the most bumpy column margins commonly strongly wavy.

Microstructure: Lamination in all specimens extremely indistinct. Where best preserved, it consists of alternating relatively lighter and darker, pale brownish stained dolomite laminae, many of the light laminae containing detrital quartz sand grains, restricted to the central parts of columns. *Light laminae* have extremely indistinct boundaries, are 0.3–2.0 mm thick, and thin markedly towards column margins. Included sand grains subrounded to subangular, grain size 0.05–0.5 mm. Dolomite hypidiotopic, of inequidimensional crystals, grain size 0.005–0.025 mm, often showing approximate rhombic outlines. There are variations in the intensity of the brownish pigmentation present in the crystals. *Dark laminae* extremely fine grained, more densely stained reddish-brown, 0.05–0.5 mm thick, most clearly visible and thickest in marginal portions of columns, but thin, markedly wrinkled, and discontinuous, frequently consisting of lenses only 1 or 2 mm long, in central part. Towards margin, dark laminae frequently merge.

Interspaces extremely narrow, 1–5 mm wide, most commonly 1–2 mm. Sedimentary filling unlaminated, consists of equal proportions of sand and dolomite matrix. Quartz sand grains subrounded, commonly 0.2–0.5 mm diam., a few up to 2 mm. Feldspar and red, extremely fine grained, possibly igneous rock fragments sub-ordinate. Matrix consists of hypidiotopic to xenotopic dolomite, with equidimensional crystals of grain size 0.005–0.03 mm, patchily recrystallized to hypidiotopic sparry dolomite of 0.03–0.05 mm grain size. Intraclasts of pale brownish fine grained dolomite, up to 5 mm long, 2 mm wide occur in places mixed with sand grains. These probably represent fragmented algal laminae.

Secondary Alteration: The generally poorly preserved microstructure of stromatolitic and interspace dolomite and its corrosion of quartz grains suggest that it is secondary. Small irregular patches of recrystallized, fine sparry dolomite are scattered throughout columns and interspaces. Layering in stromatolitic columns is extremely indistinct, and defined only by slight variations in grain size and pigmentation; this general homogeneity may be partly due to dolomitization. Dark laminae are in places disrupted, perhaps by recrystallization of the intervening light laminae. All detrital quartz grains have corroded margins, usually surrounded by a thin rim of finely crystalline sparry dolomite. Authigenic chlorite is developed in places in the interspace sediment near column margins. Small stylolites are developed locally near column margins but are unimportant. Frequent large stylolites, concordant with bedding, were seen in the field (Fig. 17a). These are up to 1 cm wide, and contain marked concentrations of sand and authigenic chlorite.

Comparisons

The stromatolites are assigned to the group *Katavia* because of their β-parallel branching, bumpy, walled columns. They are distinguished

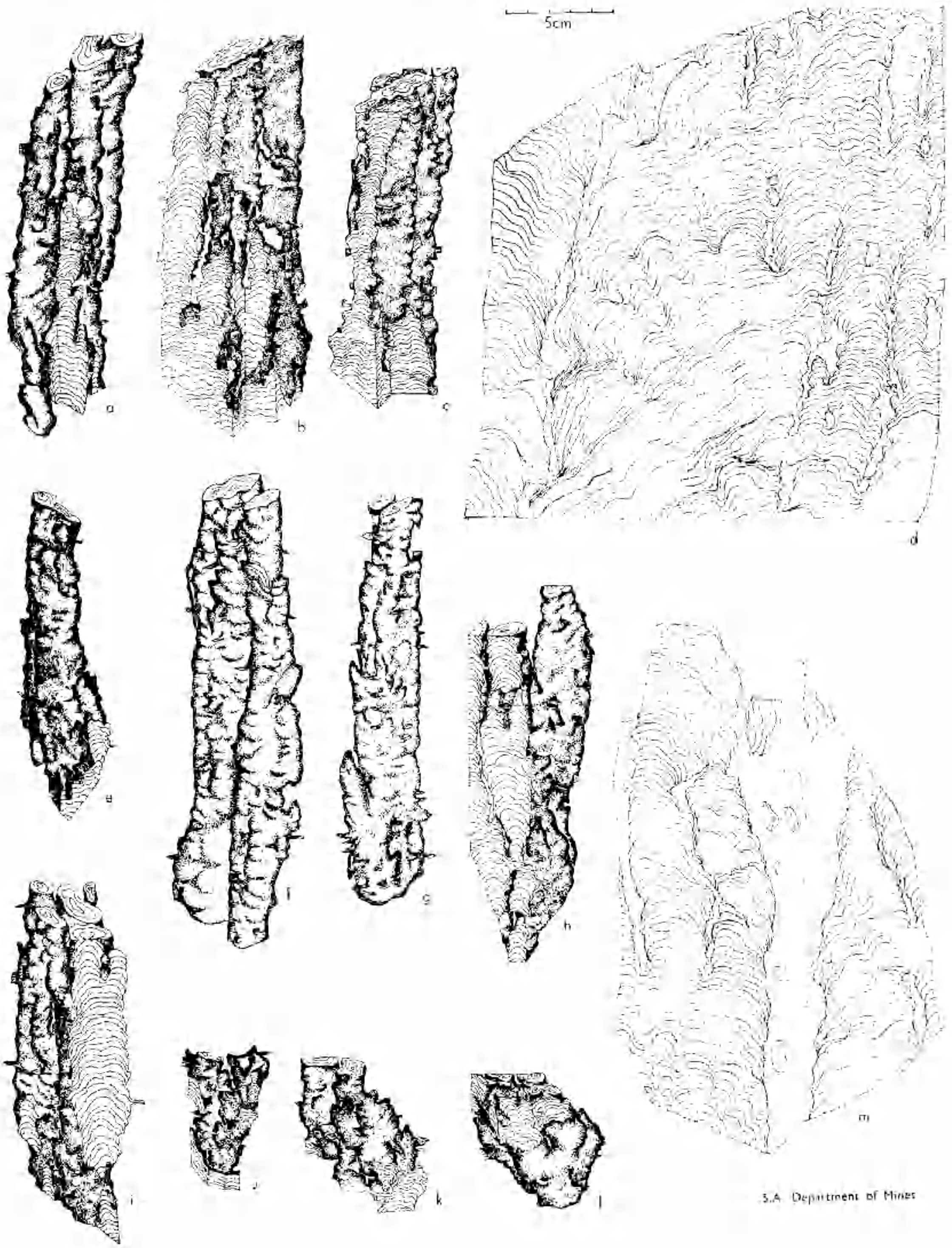

Fig. 7. (a) to (m)—*Kulparia kulparensis*, Etina Formation equivalent, near Kulpara, northern Yorke Peninsula: (a), (b), (c), (e), (i)—Holotype S380, from unit C (Fig. 8); (d), (m) —S419; junctions between two contiguous domes, unit C (Fig. 8), (m) is cut by a sand dyke, including stromatolitic fragments; (f), (g)—S420, from unit E (Fig. 8); (h)—S271, from unit C (Fig. 8); (j)—S381, (k), (l)—S270, from unit A (Fig. 8).

from most other walled stromatolites by their markedly bumpy margin structure, and from *Patomia* Krylov by their predominant simple, β-parallel branching. Like the illustrations of *Katavia karatavica* Krylov, *K. costata* has a few very short pointed projections. It is extremely similar to *K. karatavica* in its gross form, microstructure and margin structure, and is distinguished only by its more closely spaced columns and by the possession of short transverse ribs.

Distribution: In two bioherms, upper (dolomite) member of the Brighton Limestone equivalent, 3 km N of Depot Flat H.S., southern Flinders Ranges, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean of the USSR.

Group KULPARIA Preiss & Walter
(in Walter 1972: 151)

Patomia sp. nov., Glaessner, Preiss & Walter (1969, p. 1057).

Type Form: *Kulparia kulparensis* Preiss, from the Etina Formation equivalent, Umberatana Group; Yorke Peninsula, S. Aust.

Name: After the township of Kulpara, northern Yorke Peninsula, S. Aust.

Diagnosis: Long, nearly straight, parallel bumpy columns, erect or radially arranged with very frequent coalescing and bridging, moderately frequent α- and β-parallel branching and a wall between bridges; projections may be moderately frequent.

Content: *K. kulparensis* Preiss and *K. alicia* (Cloud & Semikhatov) Walter.

Comparisons

In gross form, *Kulparia* resembles *Minjaria* Krylov and *Boxonia* Korolyuk, but is distinguished by its bumpy column margins with frequent bridging and coalescing. Like *Katavia* Krylov and *Patomia* Krylov, it has a walled, bumpy margin structure; *Katavia* columns have β-parallel branching, no bridges and they rarely coalesce, while *Patomia* has frequent slightly divergent branching and very numerous pointed projections. Some illustrations of *Patomia ossica* Krylov, from the Malokaroy Suite, resemble *Kulparia* in having bumpy, long subparallel columns with fewer projections, but lack the frequent coalescing and delicate bridges of *Kulparia*. *Kulparia kulparensis* was initially assigned to *Patomia* on the basis of this similarity (Glaessner, Preiss & Walter 1969). *Kulparia* differs from *Linella* Krylov in lacking gnarled and tuberous columns, and from *Gymnosolen* Steinmann in lacking γ-parallel branching. In gross form, *Kulparia* also resembles the walled parts of *Inzeria intia* Walter but is distinguished by the absence of niches and elongated projections.

Distribution: Etina Formation equivalent, S. Aust. and Bitter Springs Formation, C. Aust.

Age: Adelaidean.

Kulparia kulparensis f. nov.

FIGS. 7, 8, 9h, 10h, 16e, 17b-f

Material: Eleven specimens from Kulpara, S. Aust.

Holotype: S380 (Figs. 7a, b, c, e, i, 17d, e) from the Etina Formation equivalent, Kulpara.

Name: After the township of Kulpara.

Diagnosis: *Kulparia* with very frequent delicate bridges, moderately frequent pointed projections and variable lamina shape, from gently to steeply convex. Microstructure diffuse, irregularly streaky.

Description

Mode of Occurrence: A bed traced for at least 400 m, its northern extension not known, while its termination in the south can be located only approximately, due to lack of exposure. Stromatolitic bed up to 13 m thick, occurs at passage from flaggy pale grey clean limestone to massive, gritty, cross-bedded limestones. The basal portion of the bed (A) (Fig. 8), commencing conformably upon the flaggy limestones, consists of short, partly divergently branching columns and pseudocolumns, in thin beds up to 15 cm thick, with numerous bridges and continuous, nearly flat-laminated layers. This is overlain by a broadly domed biostrome (C) of long, narrow, vertical, parallel, very closely spaced columns, arising from a laterally linked zone and short, broad, basal columns (B). The upper surface of the biostrome of long parallel columns bends downwards sharply at the junctions between domes, columns becoming inclined, and to some extent pseudocolumnar. The domed biostrome pattern is repeated in the overlying undulose and pseudocolumnar bed (D), again passing up into long, parallel columns (E), once more overlain by laterally linked and pseudocolumnar layers (F). Gritty, cross-bedded limestone overlies the stromatolitic sequence. Contacts between the various units cannot be accurately placed in the field, due to poor exposure and lichen cover, but were partly deduced from laboratory study of specimens (Fig. 8).

Column Shape and Arrangement: Unit (A) consists of short, vertical to slightly inclined columns, 5–20 mm wide branching frequently from a wavy laminated layer. Columns swell and constrict slightly, bear rounded bumps and occasional ribs, and coalesce frequently. Some columns terminate their growth as pointed projections (Figs. 7j, k, l, 17f); overlying unit (B) in part columnar. If present, columns broad, up to 6 cm wide, with very irregular, bumpy outlines and numerous massive bridges, grading laterally and vertically into pseudocolumns with occasional interspaces. In the main columnar units (C) and (E), columns 1–3 cm wide, swelling and constricting slightly (Fig. 17d, e). A few branches develop only into short, pointed projections (Fig. 7f, g). Length of long, parallel columns between branches 5-20 cm; the unit as a whole attains a thickness of up to 2 m, but columns not continuous throughout, as pseudocolumnar horizons intervene. Transverse sections generally rounded polygonal, lobate, elongated or irregular; circular sections relatively rare. At dome edges, columns slightly inclined (never at less than 60° to the horizontal), and bridged to a greater extent, forming pseudocolumns resembling those in units (B) and (D) (Fig. 7d, m).

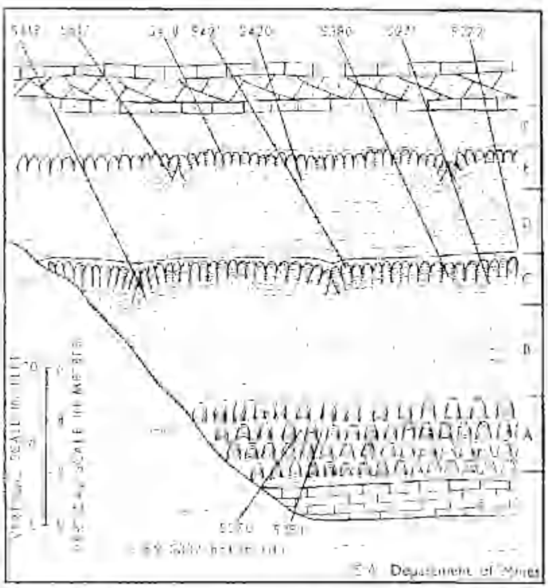

Fig. 8. Diagrammatic section of stromatolitic bed near Kulpara. The relative positions of the specimens were partly determined in the field and partly deduced from laboratory specimens.

Branching: Basal columns of unit (A) characterized by frequent, slightly divergent branching (Fig. 7j, k, l). Long, parallel columns of units (C) and (E) entirely α- and β-parallel branching. Near their bases, broad columns and pseudocolumns (4–6 cm wide) branch into several 1–3 cm columns. Above this level, α- and β-parallel branching moderately frequent. Coalescing of neighbouring columns is as frequent as branching.

Margin Structure: All columns have a markedly bumpy lateral surface; bumps 0.5–1.0 cm wide, with a relief of 1–5 mm most common. Most equidimensional, some grade into short transverse ribs, others into short pointed projections (Fig. 7f, g). Longer pointed projections (up to 3 cm) moderately rare (Fig. 7g). Delicate bridges, composed of only one or two laminae very frequent, linking most adjacent columns (Fig. 17d), usually depressed, U-shaped (only the more prominent bridges could be shown on reconstructions). Massive bridges up to 2 cm thick moderately rare. Successive delicate bridges in places only 5 mm apart. Occasionally very short peaks project down from the column margins. Wherever peaks and bridges do not occur, wall well developed. Wall most extensive in the long, narrow columns. Laminae thin towards margin, and coat surface for a distance of up to 1.5 cm. The wall involves from one to five laminae (Fig. 17d, e). The short basal columns of unit (A) have only a patchy wall, as do some of the long columns with gently convex laminae (Fig. 17b).

Lamina Shape very variable; generally narrowest columns have steepest laminae, while broad basal columns and pseudocolumns have gently convex and rectangular laminae. Of the laminae measured, 69% have ratios of h/d between 0.3 and 0.8, but narrow columns and projections usually have h/d greater than 1.0 (Fig. 10h). Fig. 9h illustrates commonly occurring lamina shapes. Most laminae gently wavy, usually with wavelength 2–3 mm.

Microstructure: Lamination indistinct and streaky (Fig. 17d, e). Where best preserved, fairly continuous wavy dark laminae persist from wall to wall, and alternate with light laminae. *Dark laminae* composed of very fine grained silty limestone, consisting of equidimensional xenotopic calcite of grain size 0.003–0.01 mm, with included subrounded quartz and a little feldspar, of grain size up to 0.08 mm. Dark laminae 0.05–0.4 mm thick,

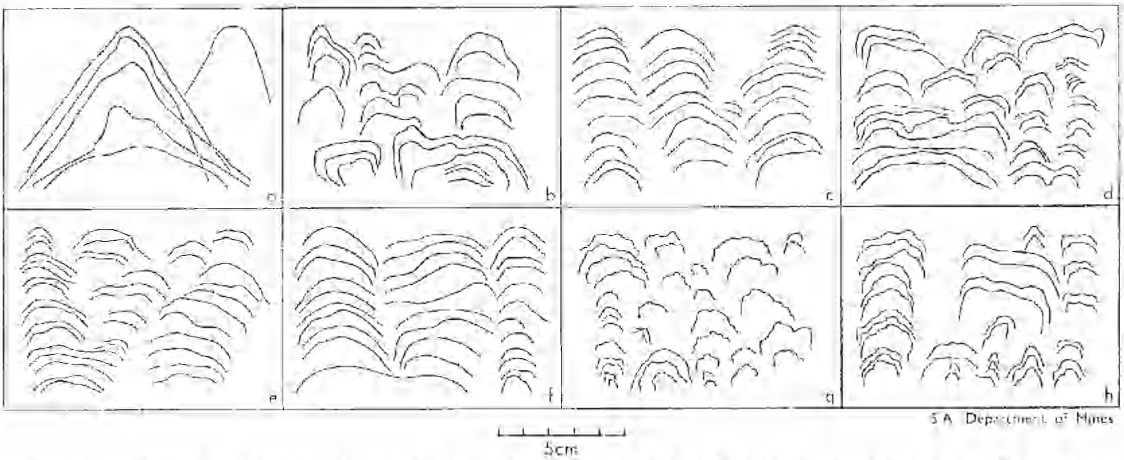

Fig. 9. Examples of lamina shapes of the stromatolites, traced from thin sections. (a)—*Conophyton garganicum garganicum*; (b)—*Gymnosolen* cf. *ramsayi*; (c)—*Inzeria* cf. *tjomusi*; (d)—*Inzeria conjuncta*; (e)—*Inzeria multiplex*; (f)—*Jurusania burrensis*; (g)—*Katavia costata*; (h)—*Kulparia kulparensis*.

generally thickest in central part of a column. Boundaries diffuse. At column margins, dark laminae thin to a thickness of about 0.05 mm and coat surface of column. Intervening light laminae thinned more, and lens out some distance down the wall, so that here dark laminae merge. *Light laminae* up to 0.7 mm thick in central parts of steeply convex laminated columns, but thin rapidly towards the edges. They consist of inequigranular xenotopic to hypidiotopic calcite of grain size 0.015–0.05 mm, with minor rounded quartz silt, of grain size up to 0.08 mm. In the short columns of unit (A) lamination is better preserved (Fig. 17f). Dark, homogeneous laminae, 0.15–1.0 mm thick, are composed of pale brownish and greenish pigmented, almost equigranular xenotopic calcite, of grain size 0.003–0.01 mm, with inclusions of detrital quartz silt of grain size 0.02–0.04 mm. In places, they have sharp lower boundaries, but grade upwards into light laminae, which are 0.3–1.5 mm thick, but thin towards the column margins, and are composed of slightly coarser, silty, xenotopic calcite, of grain size 0.015–0.02 mm. Detrital quartz grains are up to fine sand size (0.2 mm). All laminae extend uninterrupted across the width of columns, unlike laminae in the upper, long parallel columns.

Interspaces generally very narrow (1–5 mm) in units (C) and (E), but wider in basal columns of unit (A). Their sedimentary fill includes medium to coarse clastics, both terrigenous and carbonate. Generally, quartz much coarser than that incorporated into columns. The sediment consists of approximately 40% quartz (well-rounded, grain size 0.5–3 mm, finer grains tending to be subangular), 5% feldspar (rounded to subangular cloudy micro-

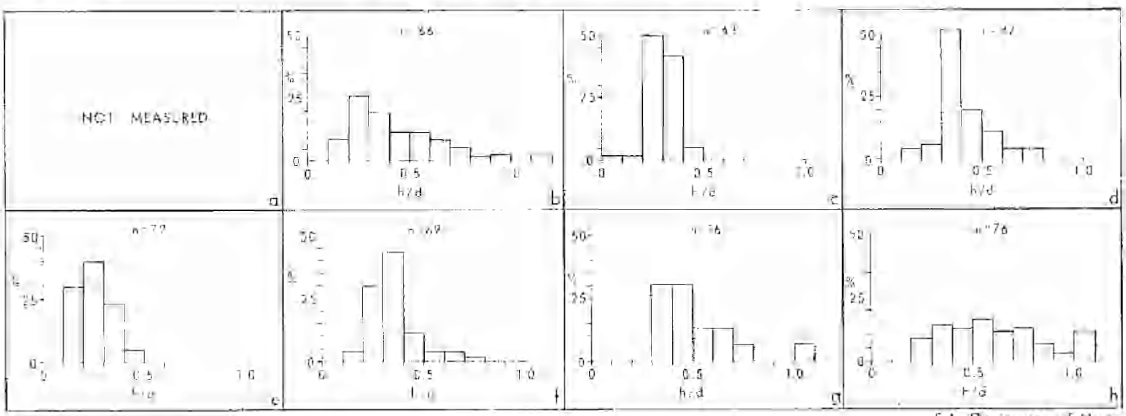

Fig. 10. Frequency distribution of lamina convexities h/d for stromatolites illustrated in Fig. 9.

cline, up to 3 mm grain size), 5% rock fragments (rounded fragments, up to 4 mm, of quartz-feldspar rock, quartzite and rare chert), 30% carbonate allochems (including flat pebbles 2–4 mm long, flat pebbles coated with 3 or 4 pale and dark laminae, recrystallized ooids with dolomitic rims and rare composite grains cemented by dark dolomitic rims) and 20% cement (sparry, hypidiotopic mosaic calcite, of grain size 0.015–0.06 mm cementing allochems and terrigenous detritus, in places replacing the rims of these grains). Sediment poorly bedded. Presence of wall between bridges on columns indicates that sediment was filled in periodically. After one influx of sediment, a bridge formed over it, then the interspace remained vacant while the column grew another centimetre or so, before the next influx.

Secondary Alteration: During diagenesis, the carbonate of the long columns was partly recrystallized and dolomitized; some dark laminae were preferentially dolomitized, and clays were apparently redistributed into a fine network of cracks and stylolites (Fig. 17e). In places, the shape of laminae is completely disrupted. Near the dome margins, lenticular patches of sparry calcite occur within columns, either concordant with the laminae or at a high angle to them. These structures predate clastic dykes which cut both stromatolite columns and interspace sediment (both of which must have been lithified at the time) (Fig. 17b). The filling of the dyke consists of angular to subrounded, poorly sorted quartz, of grain size 0.05–1 mm. The sand is tightly packed, the finest angular grains forming the matrix. Calcite cement is almost totally absent; quartz grains are coated with iron oxide rims. In places, the filling process has actively eroded the walls of dykes, so that disoriented fragments of the surrounding limestone occur as inclusions in the sand (Fig. 17b). The dykes probably formed by jointing of the already lithified stromatolitic bed, especially between adjacent domes. Concordant stylolites, concentrated at definite levels in the structures, where they are only 1 or 2 mm apart, clearly postdate the sand-dykes. Stylolites partly follow the lamination, and partly cut across it. Vertical calcite veins up to 1 cm wide, consisting of coarse, euhedral crystals, post-date the stylolites, and are especially prominent in the junctions between domes, which were persistently subject to jointing. Dolomitization apparently post-dates the formation of veins and stylolites, and is therefore very late diagenetic.

Comparisons

These stromatolites have already been compared to other groups. *Kulparia kulparensis* is distinguished from *K. alicia* (Cloud and Semikhatov) Walter, by its frequent delicate bridges, generally more steeply convex laminae, and by the presence of moderately frequent pointed projections.

Distribution: Etina Formation equivalent, Umberatana Group, 7 km south of Kulpara, northern Yorke Peninsula, S. Aust.

Age: Late Adelaidean, correlated with the Late Riphean or Vendian of the USSR.

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Fig. 11. *Conophyton garganicum garganicum*, from a raft in the Paratoo Diapir: (a)—Near-axial section in outcrop of two adjacent columns illustrating margin structure. The pen is 15 cm long. Arrows indicate irregular column margins; (b)—Transverse sections of columns in outcrop, illustrating both circular and lanceolate shapes. The pen is 15 cm long; (c)—Outcrop section of broadly domed basal zone, which gives rise upwards to conically laminated columns; (d)—Thin section of crestal zone, brecciated perhaps by compaction of lithified laminae. Specimen No. S277; (e)—Details of lamination, illustrating macrolaminae, detrital carbonate granules (indicated by arrows), and swelling of some laminae. Thin section, specimen No. S214; (f)—Details of crestal zone illustrating contorted and thickened lamination. Axial longitudinal section. Thin section, specimen No. S532.

Fig. 12. (a)—*Conophyton garganicum garganicum* (Spec. No. S214). Longitudinal axial thin section illustrating crestal zone, lamination, and deflexed margins of laminae. The thick continuous bands are actually macrolaminae. Natural size; (b), (c)—*Gymnosolen* cf. *ramsayi*, from boulders in a conglomerate in the Tapley Hill Formation, near Wilson, Flinders Ranges: (b)—S388. Longitudinal thin section of vertical, branching columns, with intraclast breccia in interspaces. Natural size; (c)—S387. Longitudinal thin section of inclined columns interpreted as derived from a bioherm margin.

Fig. 13. (a)—*Gymnosolen* cf. *ramsayi* from near Wilson. Longitudinal slab of regular, walled columns interpreted to be derived from a bioherm centre. Specimen No. S388; (b) to (e)—*Inzeria* cf. *tjomusi*, from the middle limestone of the Wundowie Limestone Member, Burr Well, northern Flinders Ranges; (b)—Columnar portion of a bioherm illustrating columns with niche-projections. Note stylolites at base; (c)—Domed basal part of bioherm with continuous lamination; the upper columnar portion is separated by a stylolitic zone. Hammer is 30 cm long; (d)—Columnar zone overlying continuously laminated basal portion of bioherm. Note stylolitic zone at pencil point. Pencil 17 cm long; (e)—Longitudinal thin section, illustrating subcylindrical columns with altered margins and interspaces, gently convex to low conical laminae and a niche-projection. The basal part is intensely cut by stylolites. Specimen No. S452.

Fig. 14. (a), (b)—*Inzeria conjuncta*, Brighton Limestone equivalent, Depot Creek, southern Flinders Ranges; (a)—Longitudinal thin section of broad, basal columns with niche-projection. The laminae are alternating dark, dolomitic, and light, calcitic. Holotype, S402; (b)—Longitudinal thin section of inclined, tuberous columns from bioherm margin. Specimen No. S403; (c), (d)—*Inzeria multiplex*, Brighton Limestone equivalent, west of Mount Remarkable, southern Flinders Ranges; (c)—Longitudinal thin section of vertical columns. Natural size. Holotype, S385; (d)—Longitudinal slab of same specimen.

Fig. 15. (a)—*Inzeria multiplex*, Brighton Limestone equivalent, east of Yednalue, southern Flinders Ranges. Longitudinal thin section. Specimen No. S499; (b) to (e)—*Jurusania burrensis*, upper limestone of the Wundowie Limestone Member, Burr Well, northern Flinders Ranges; (b)—Smooth cylindrical vertical columns near a bioherm margin. Hammer is 30 cm long; (c)—Contiguous spherical bioherms; (d)—Longitudinal thin section illustrating dichotomous a-parallel branching in cylindrical columns. Specimen No. S482; (e)—Longitudinal thin section of narrower cylindrical columns with streaky microstructure. Holotype S543.

Fig. 16. (a)—*Jurusania burrensis*. Longitudinal thin section of columns arising from undulating stromatolites at base. Specimen No. S481; (b) to (d)—*Katavia costata*, from dolomitic "member" of the Brighton Limestone, Depot Creek; (b)—Long, vertical columns in longitudinal outcrop section. Hammer is 30 cm long; (c)—Transverse section of columns in outcrop. Pen is 15 cm long; (d)—Longitudinal thin section illustrating indistinct lamination and walled columns. Interspaces are filled with sandy dolomite. Holotype, S175. Natural size. (e)—*Kulparia kulparensis*, Etina Formation equivalent, Kulpara. Part of outcrop of cylindrical columns. Pen is 15 cm long.

Fig. 17. (a)—*Katavia costata*, Brighton Limestone, Depot Creek, southern Flinders Ranges. Margin of a bioherm showing inclination of columns at right of photograph; (b) to (f) *Kulparia kulparensis*, Etina Formation equivalent, Kulpara, northern Yorke Peninsula; (b)—Longitudinal thin section illustrating a sand dyke post-dating the lithification of the stromatolites. Incorporated in the dyke filling are fragments of the wall rock. Specimen No. S420; (c)—Outcrop transverse sections of lobate columns. Pen is 15 cm long; (d), (e)—Longitudinal thin sections of columns; holotype S380; (f)—Small irregular columns from Unit A at the base of the bed; longitudinal thin section. Specimen No. S270.

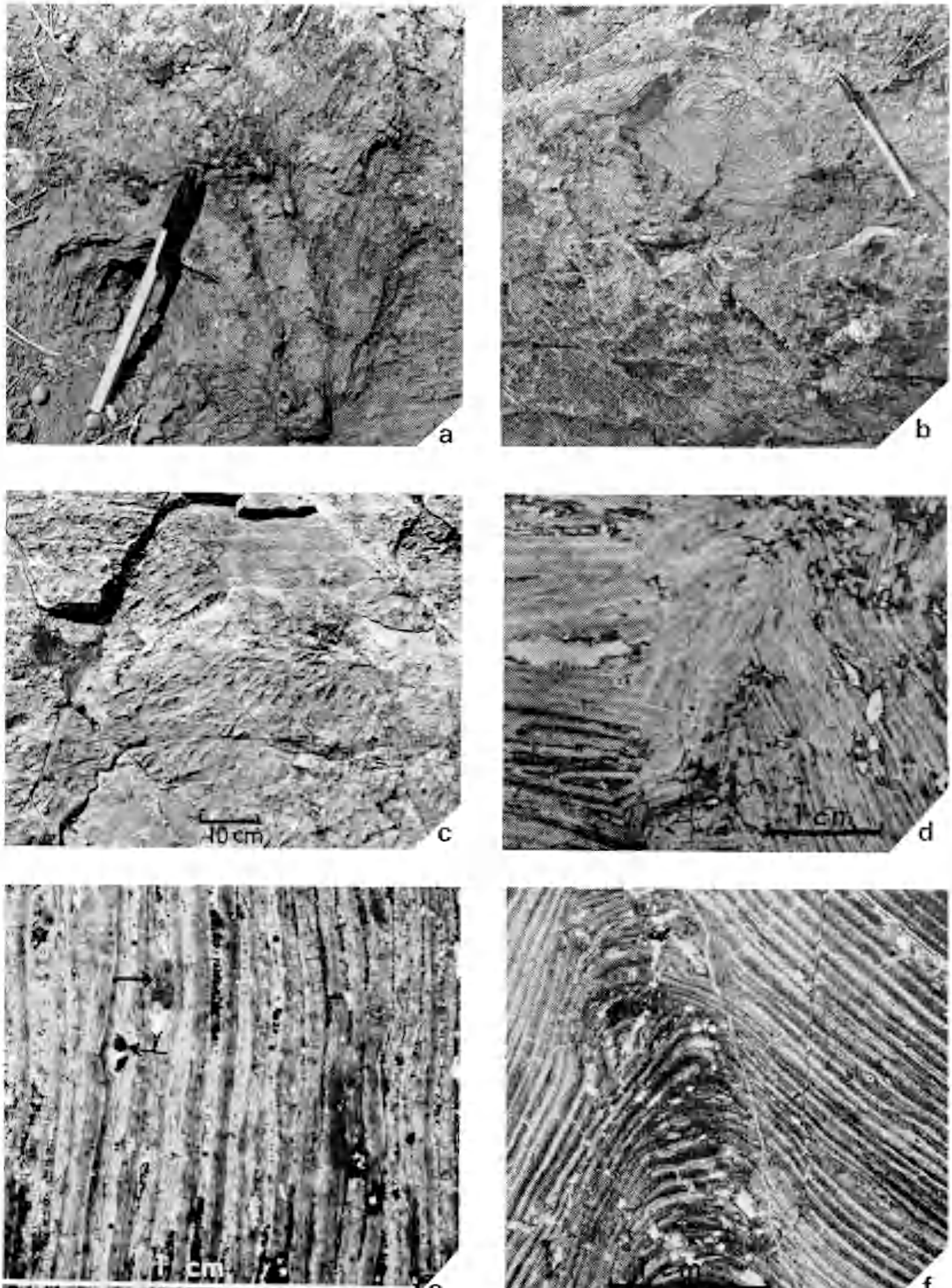

FIG. 11

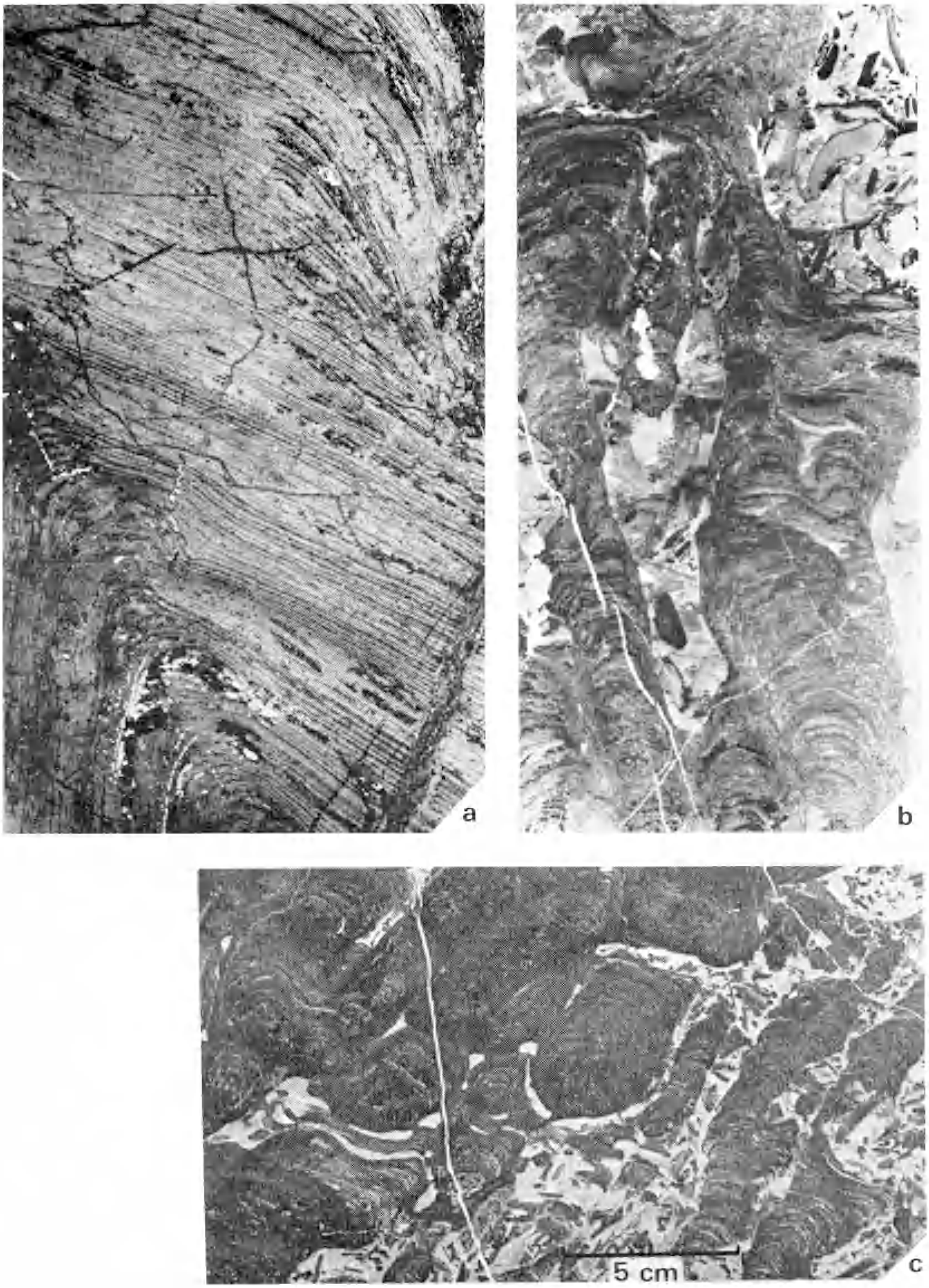

FIG. 12

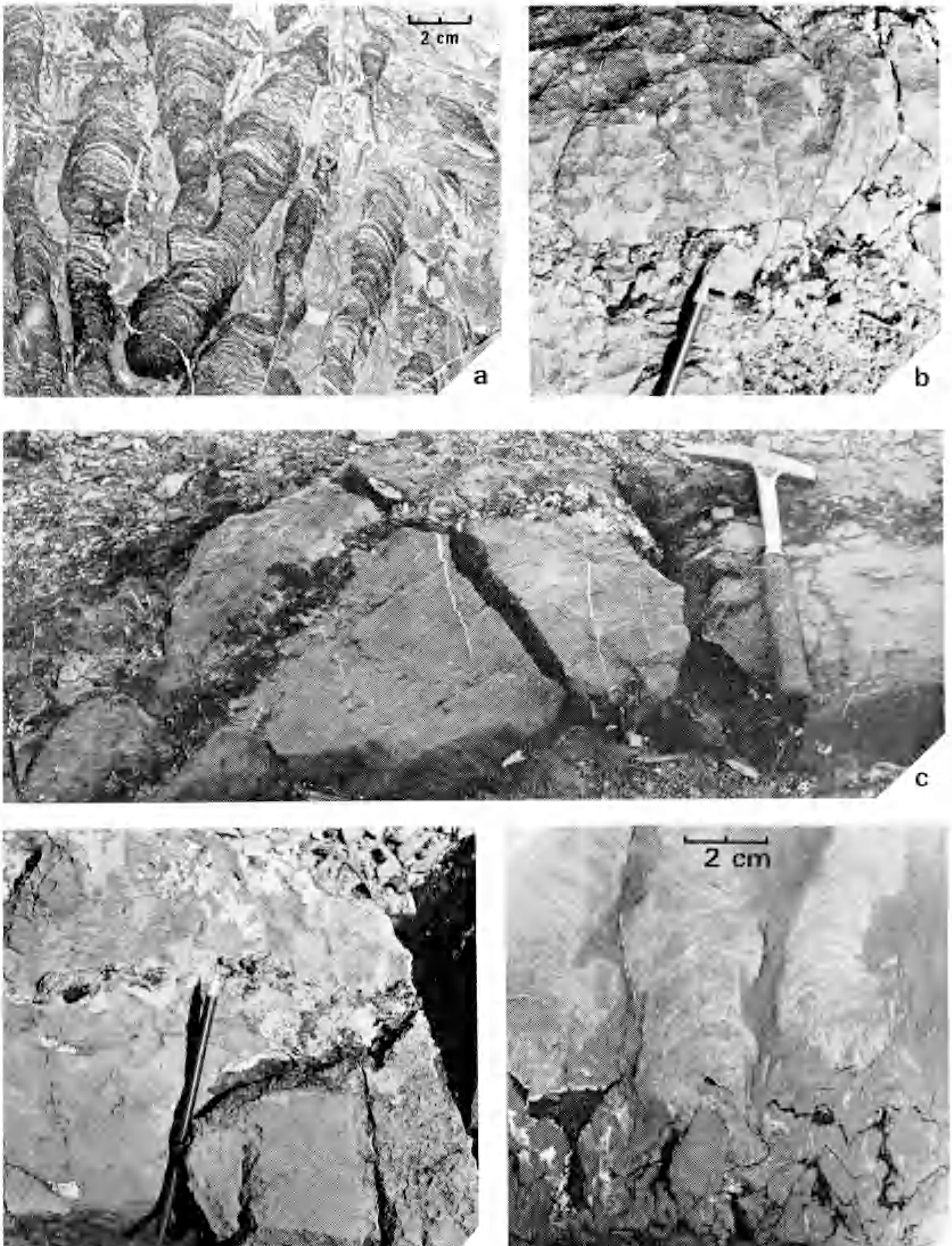

FIG. 13

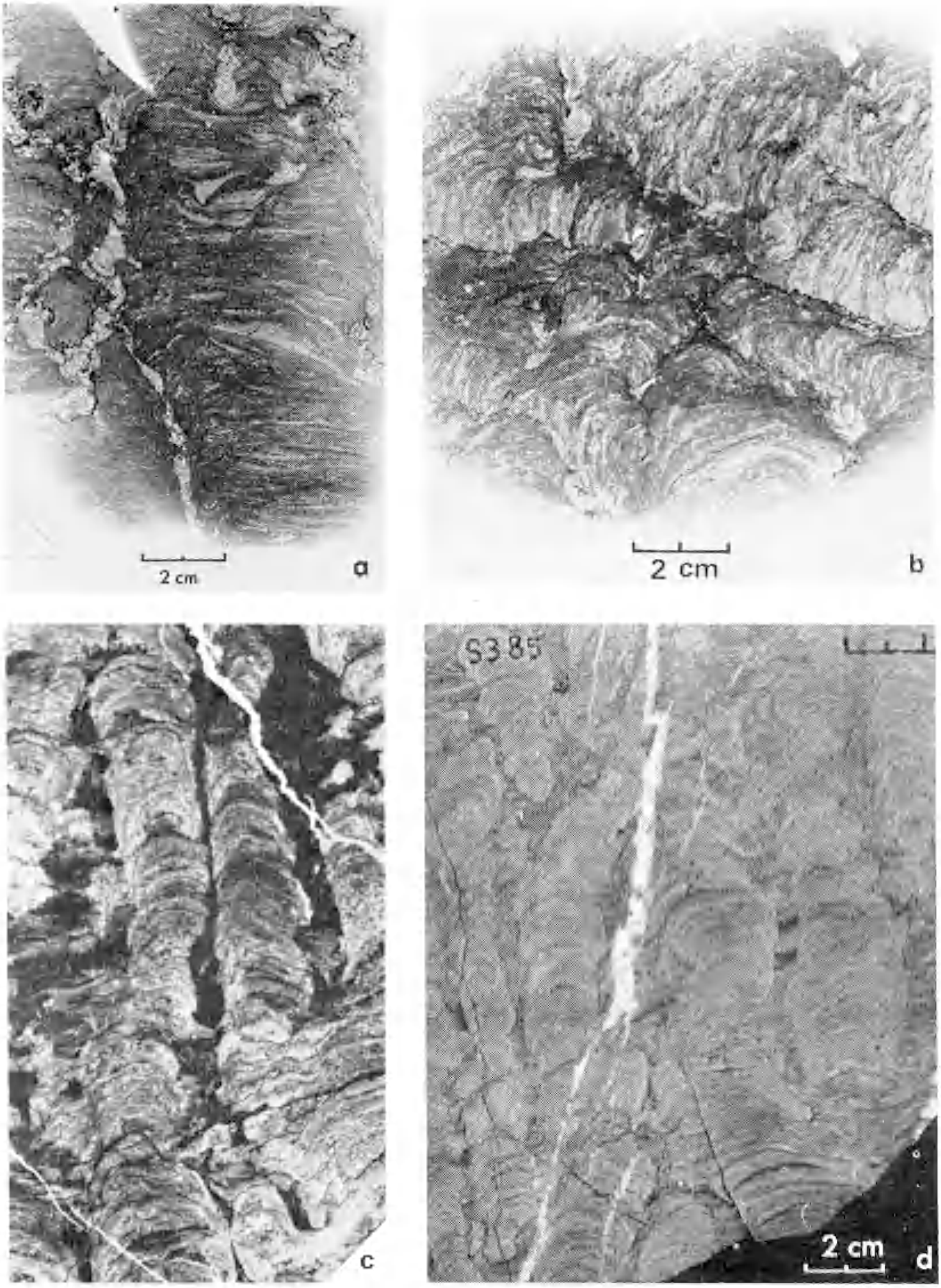

FIG. 14

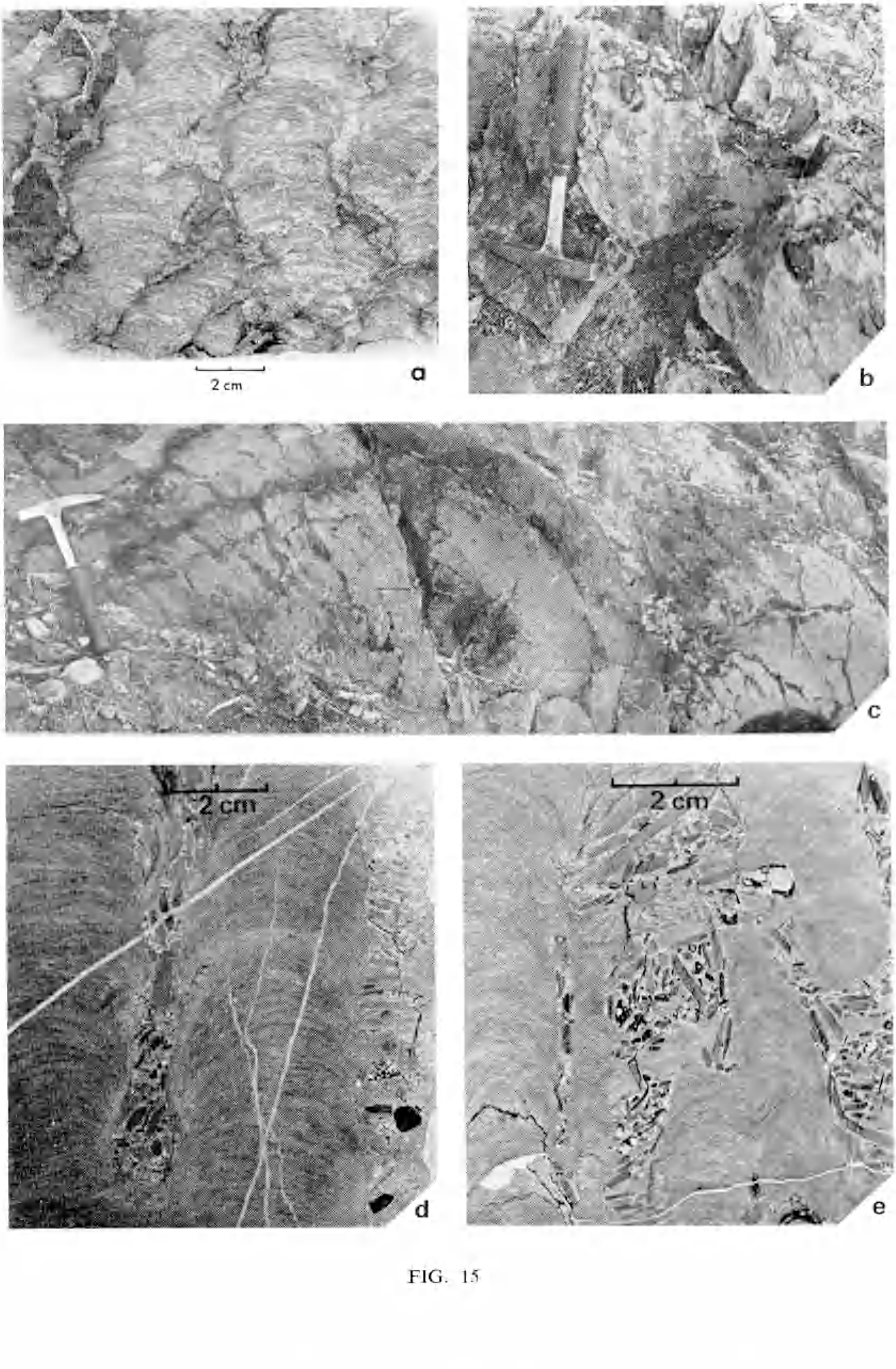

FIG. 15

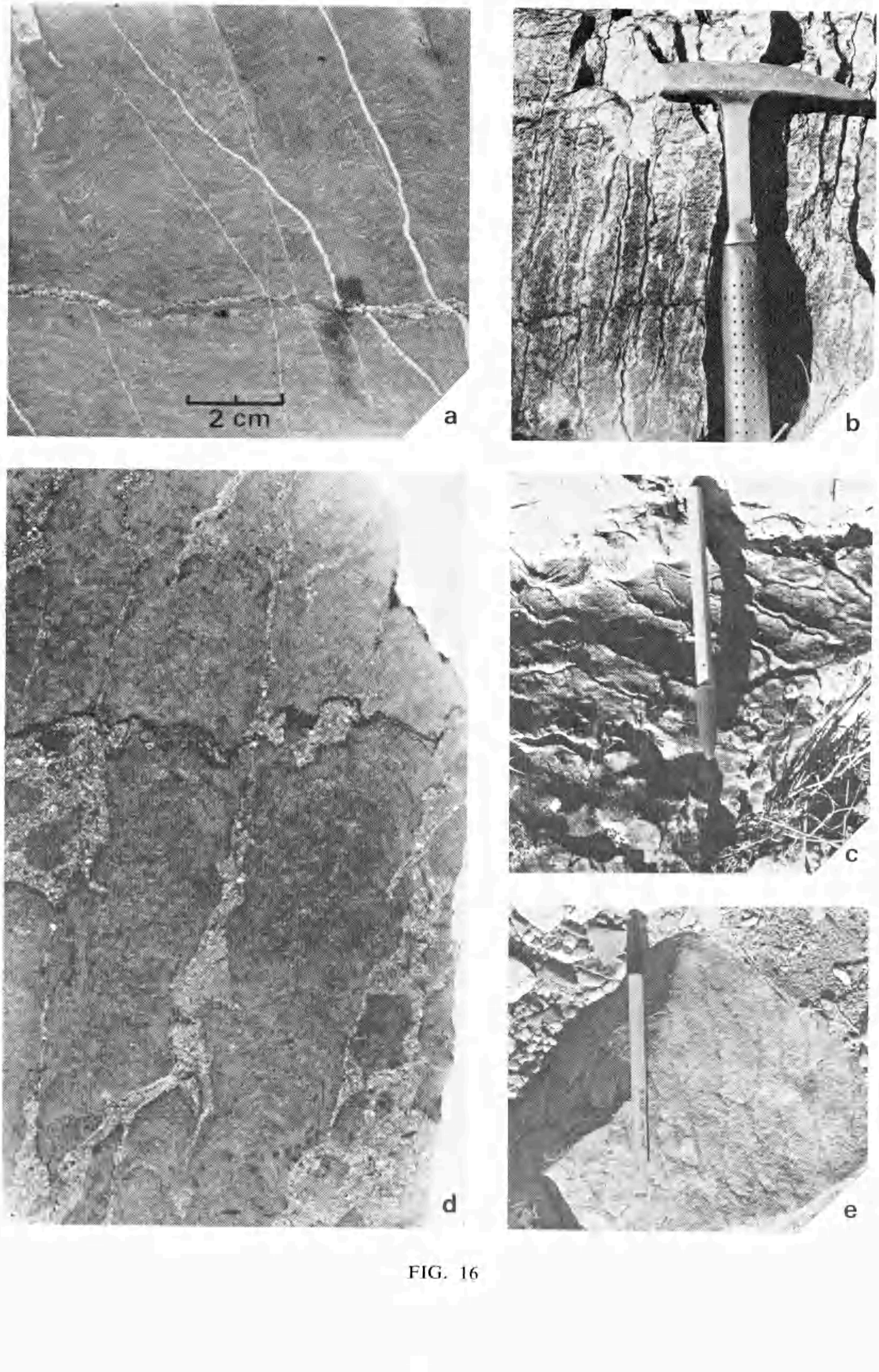

FIG. 16

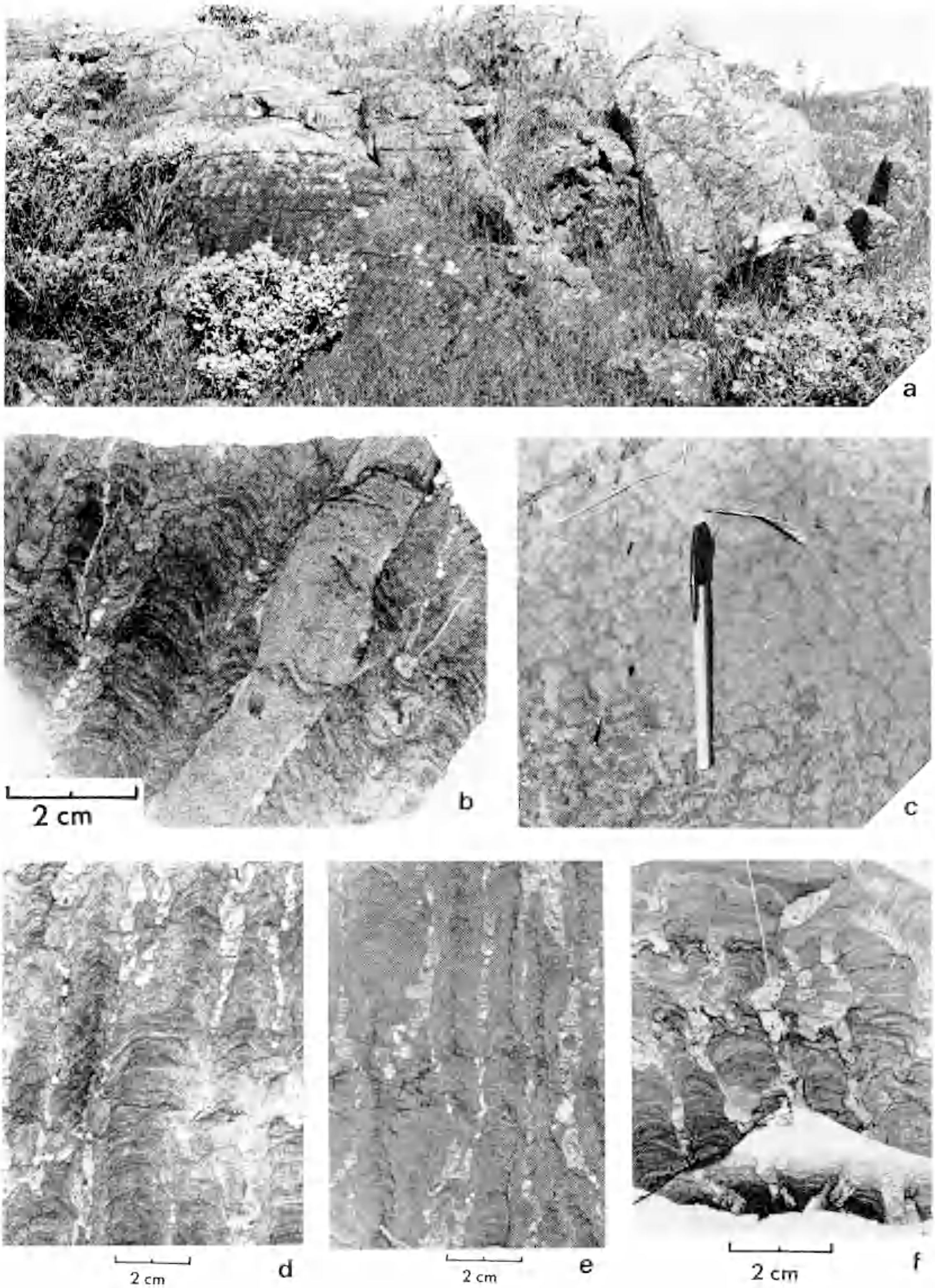

FIG. 17